Environments Favorable for Heavy Snow Across the Upper Mississippi River Valley Region: A Composite Study (2011)

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Objective

- Attain synoptic and mesoscale forcing environment information about past heavy snowfall events in the region.
  - Gain insight into the evolution of these environments.
  - Use for training.

<u>Improve Our Forecasts</u>

Methodology

Creating a Composite

- Identified heavy snow cases meeting warning criteria.
  - 6 or more inches in a 12 hour period near the La Crosse WFO forecast area.
  - Mainly from volunteer Cooperative Data Network.
  - Period: January 1979 to March 2009.

Methodology

Creating a Composite

- For each heavy snow case:
  - Identified the 850mb low track using North American Regional Reanalysis (NARR) data.
  - Defined Time=0hr when the 850mb low track crossed the 91st meridian.
    - Crosses through La Crosse forecast area.
    - Within hours (+/- 0-3h) of heaviest snowfall.
  - Grouped the cases:
    - Northwest (NW) and Southwest (SW) flow.
    - Split the SW system tracks into deepening (SW D) and steady state/weakening (SW SS/W).

Methodology

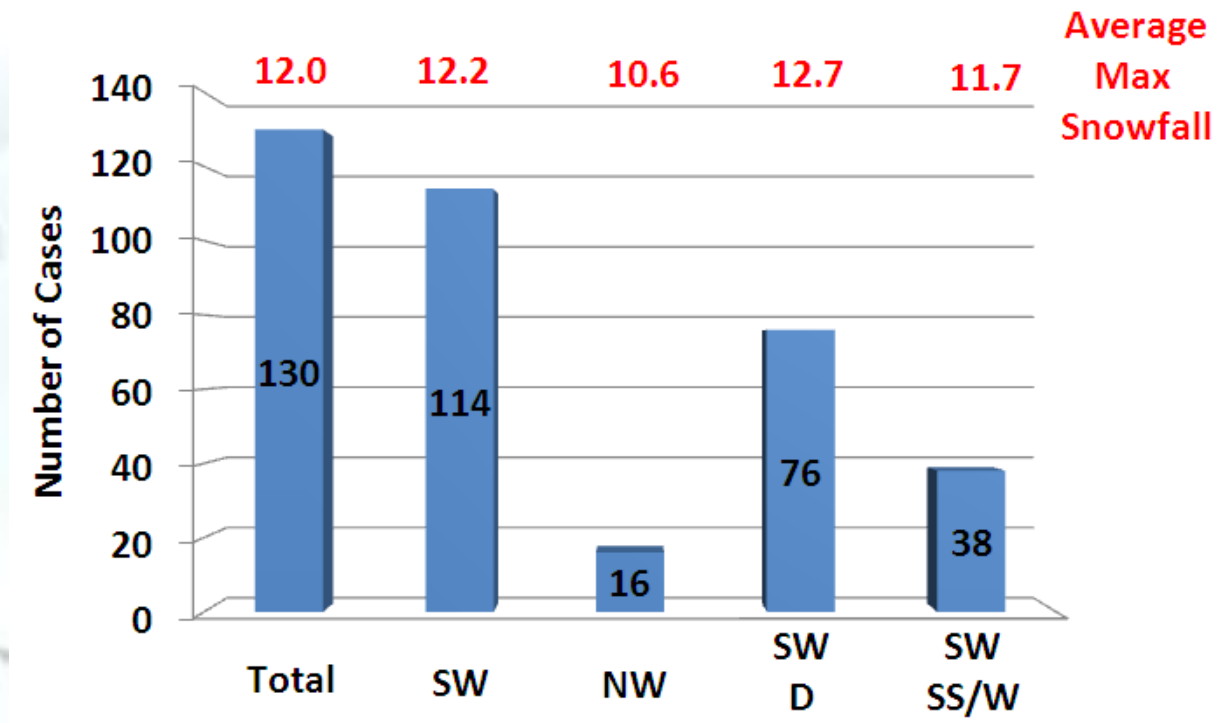
Creating a Composite

- Used the NARR 40 km data and GEMPAK to composite the meteorological parameters (Saint Louis University).

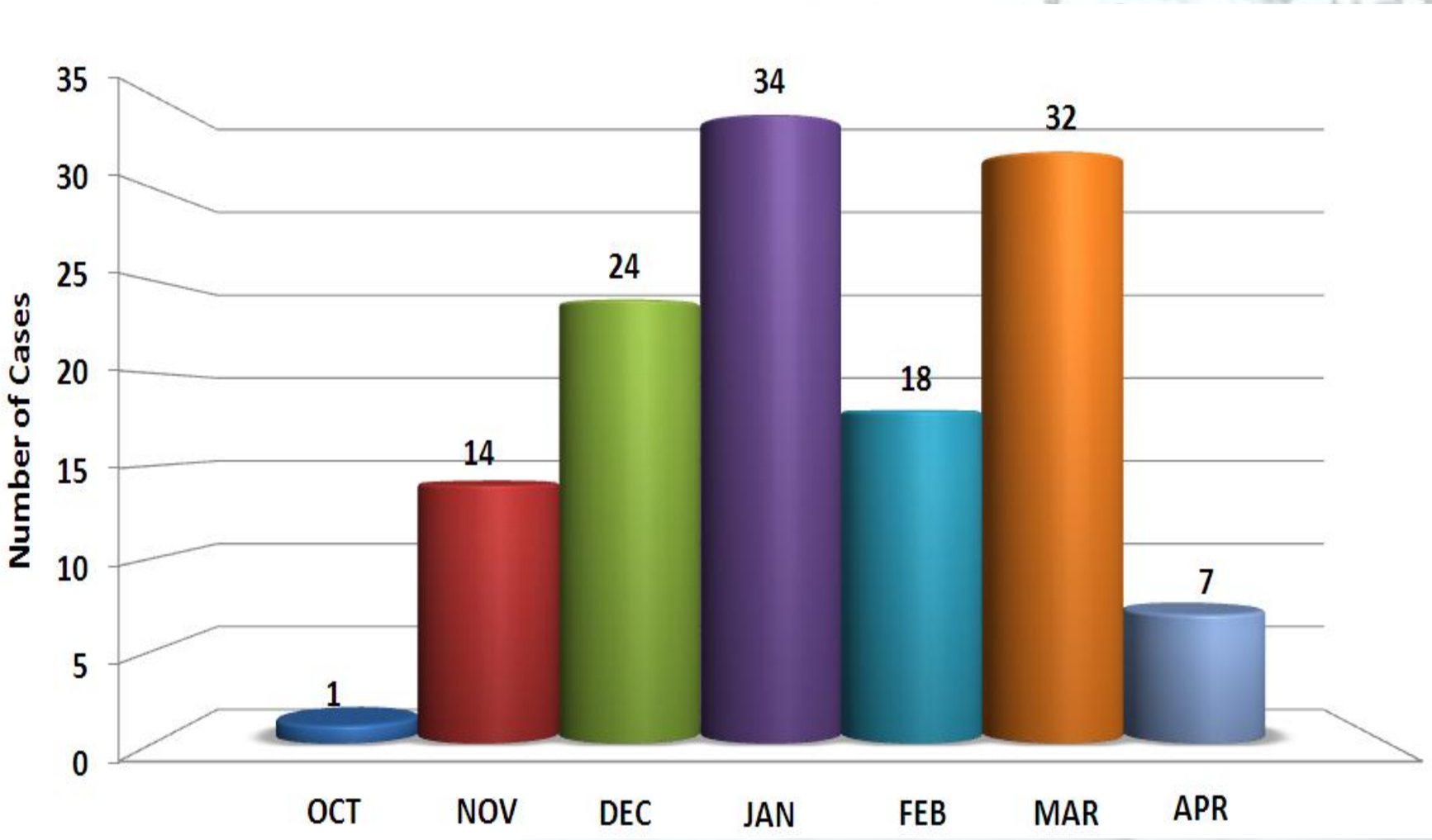
- Composited on the 850mb low center at t=0h.
  - Created composites +/- 18 hours from t=0, every 6 hours.

Case Breakdown

- 130 cases
- 114 cases southwest low tracks ~ 88% of cases
- 16 cases northwest low tracks ~ 12%

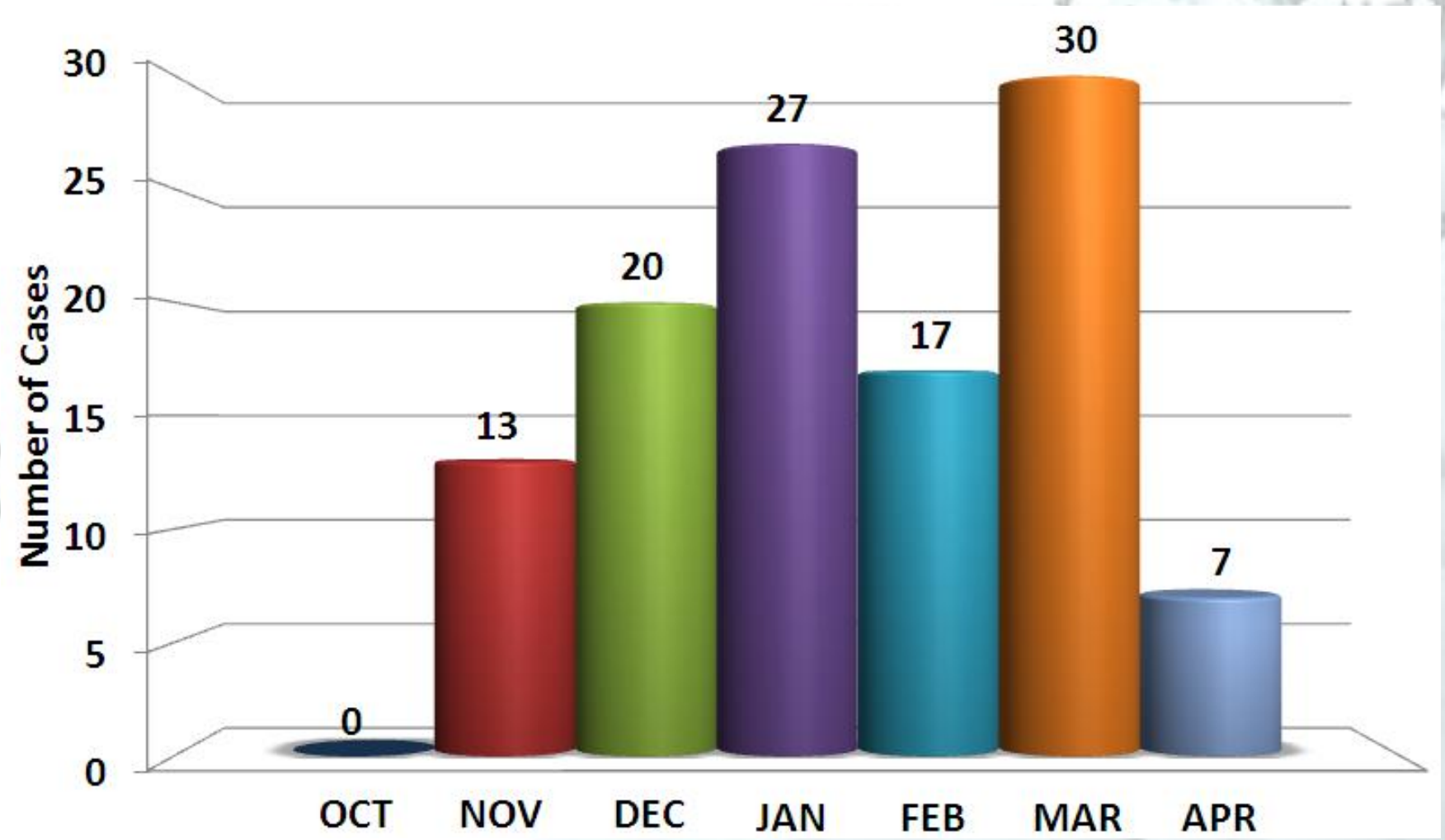


Total Cases By Month

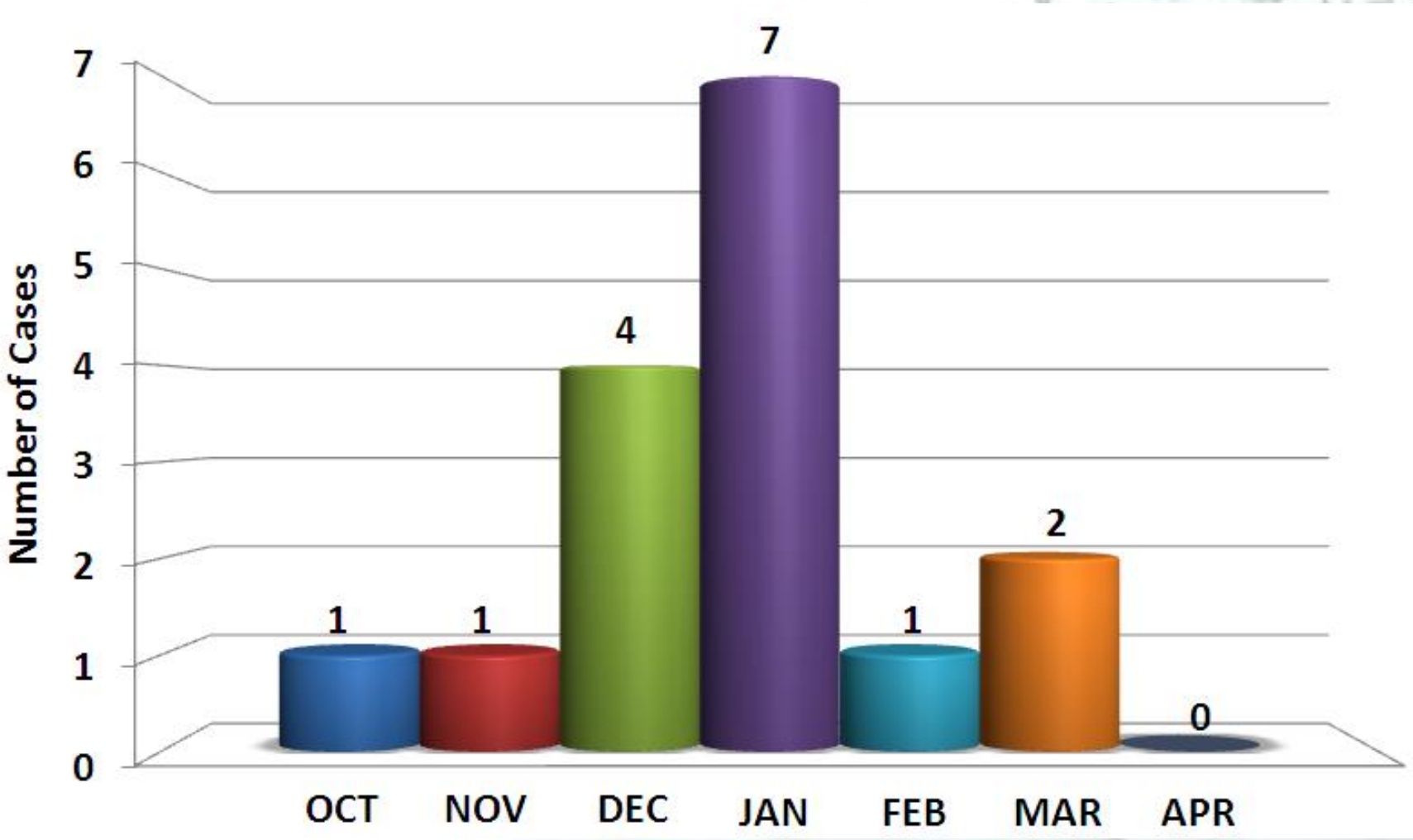


50%

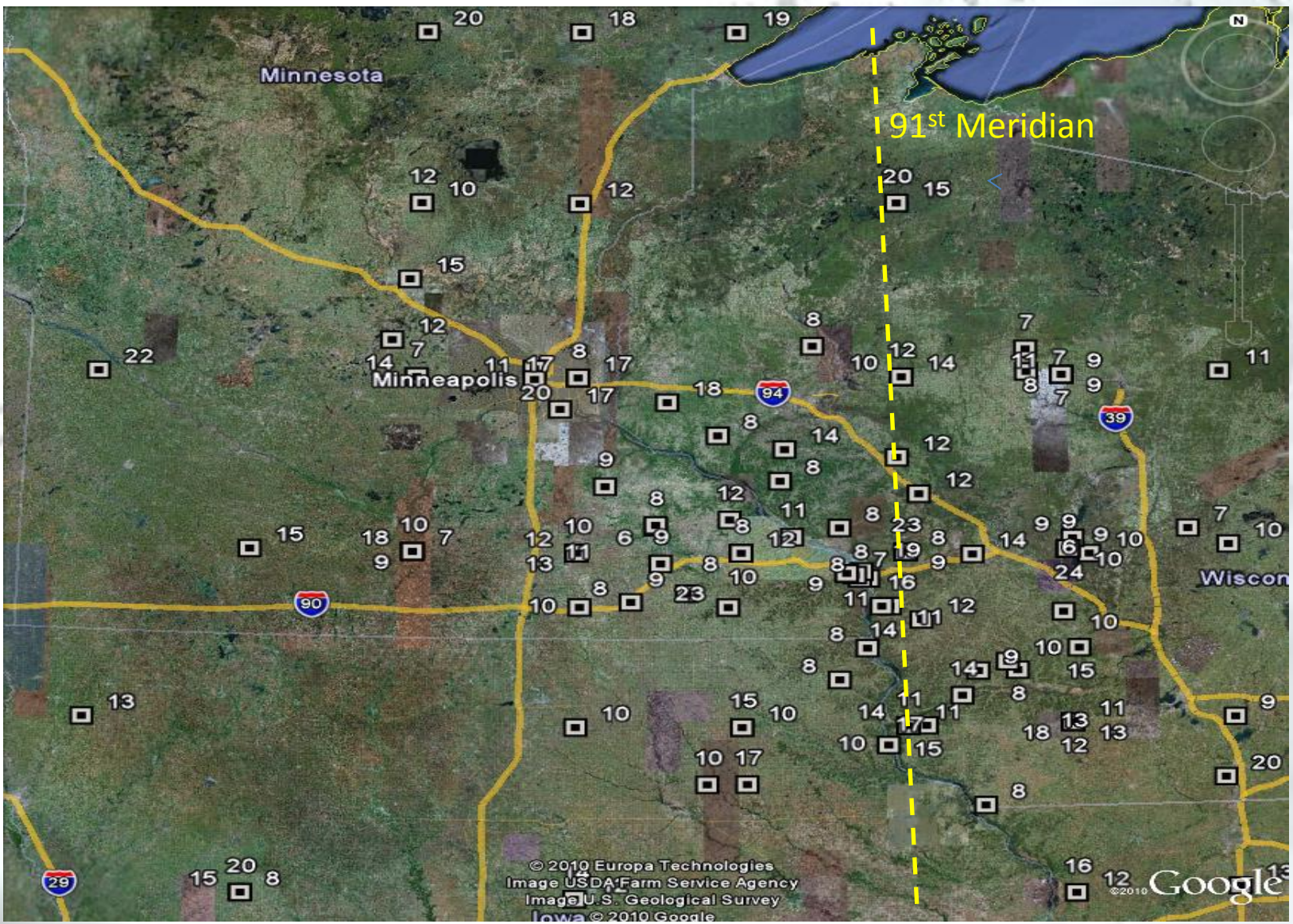
Southwest Cases By Month



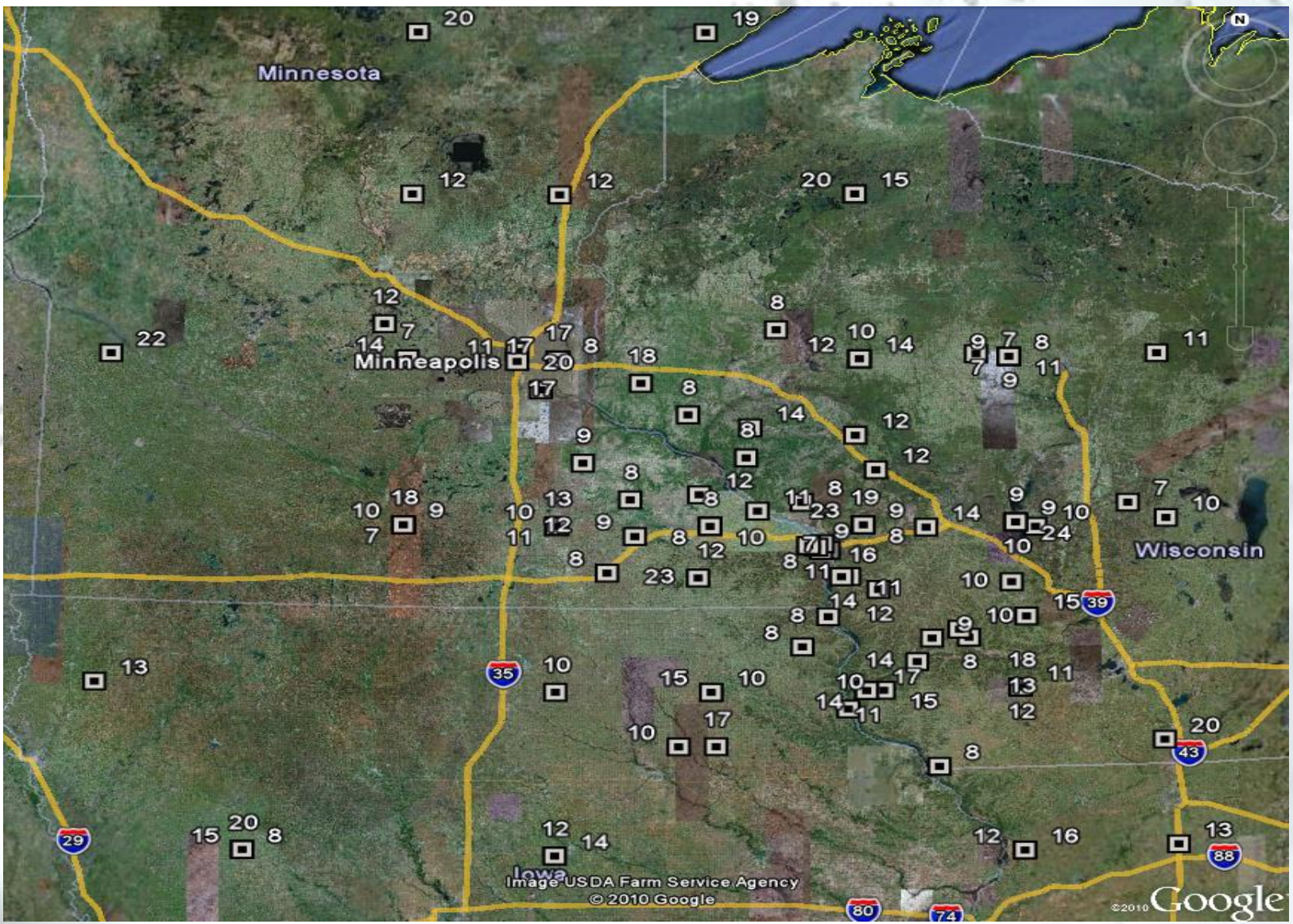
Northwest Cases By Month



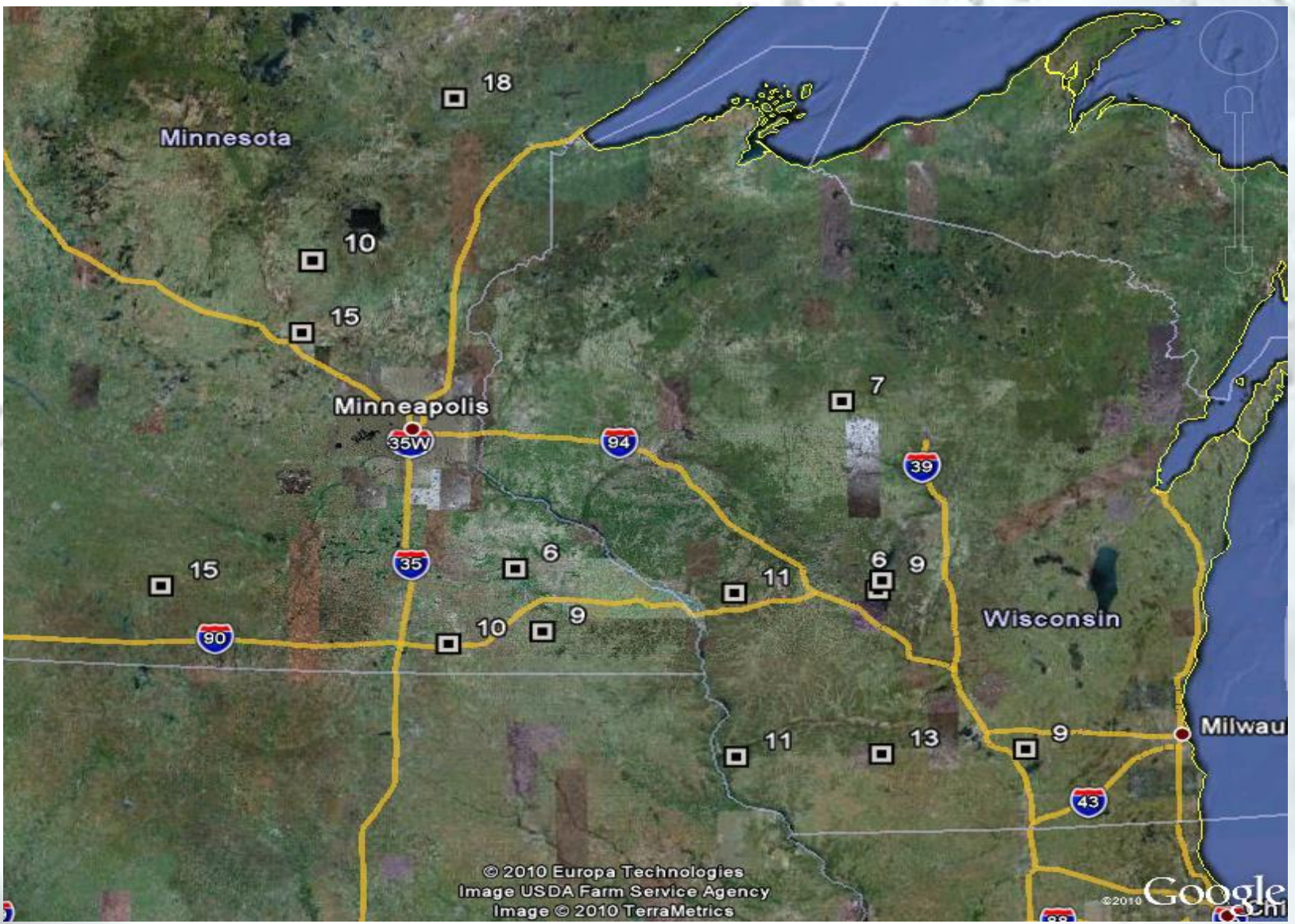
Max Snowfall Amount: All Cases



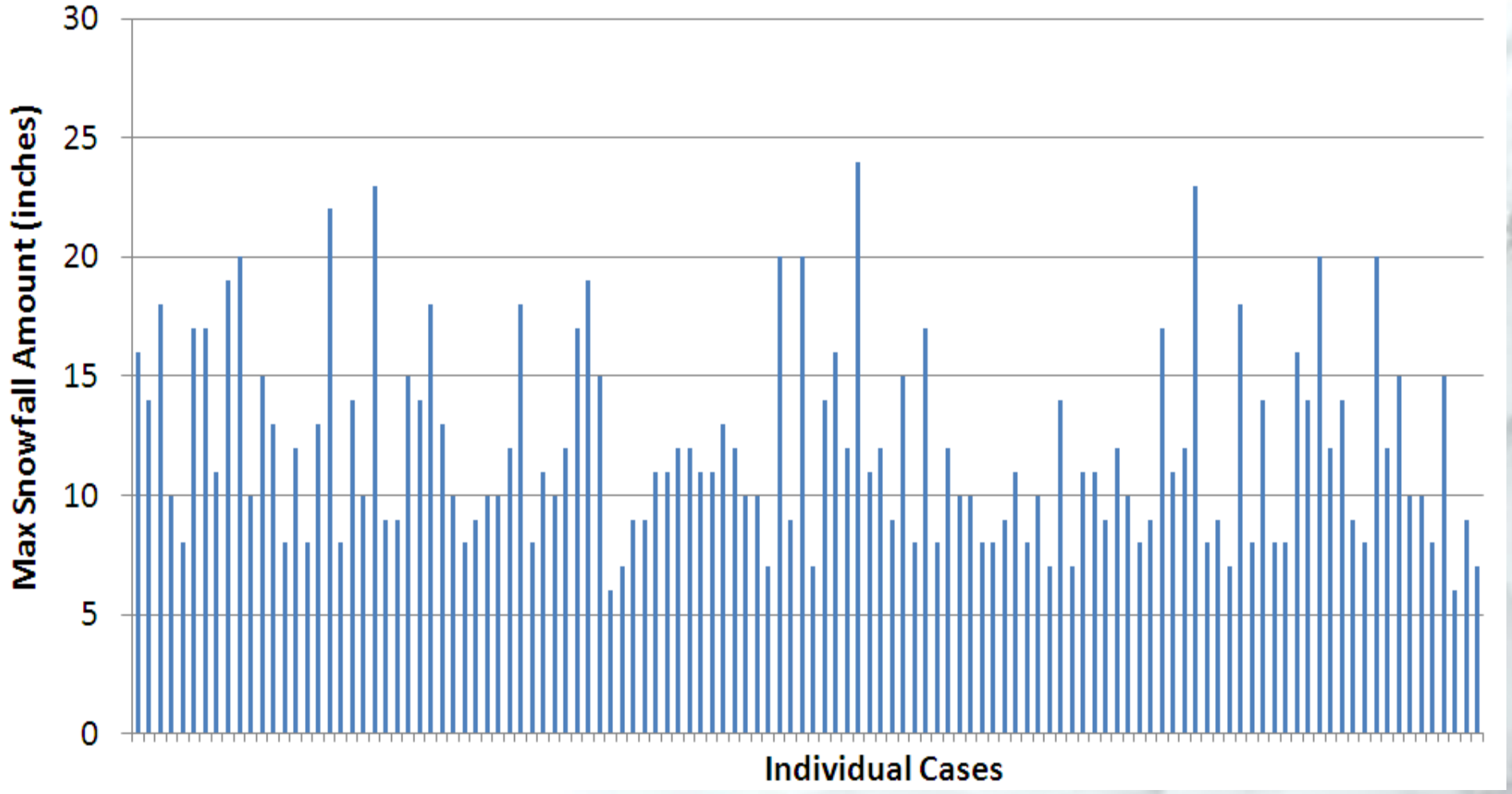
Max Snowfall Amount: SW Cases



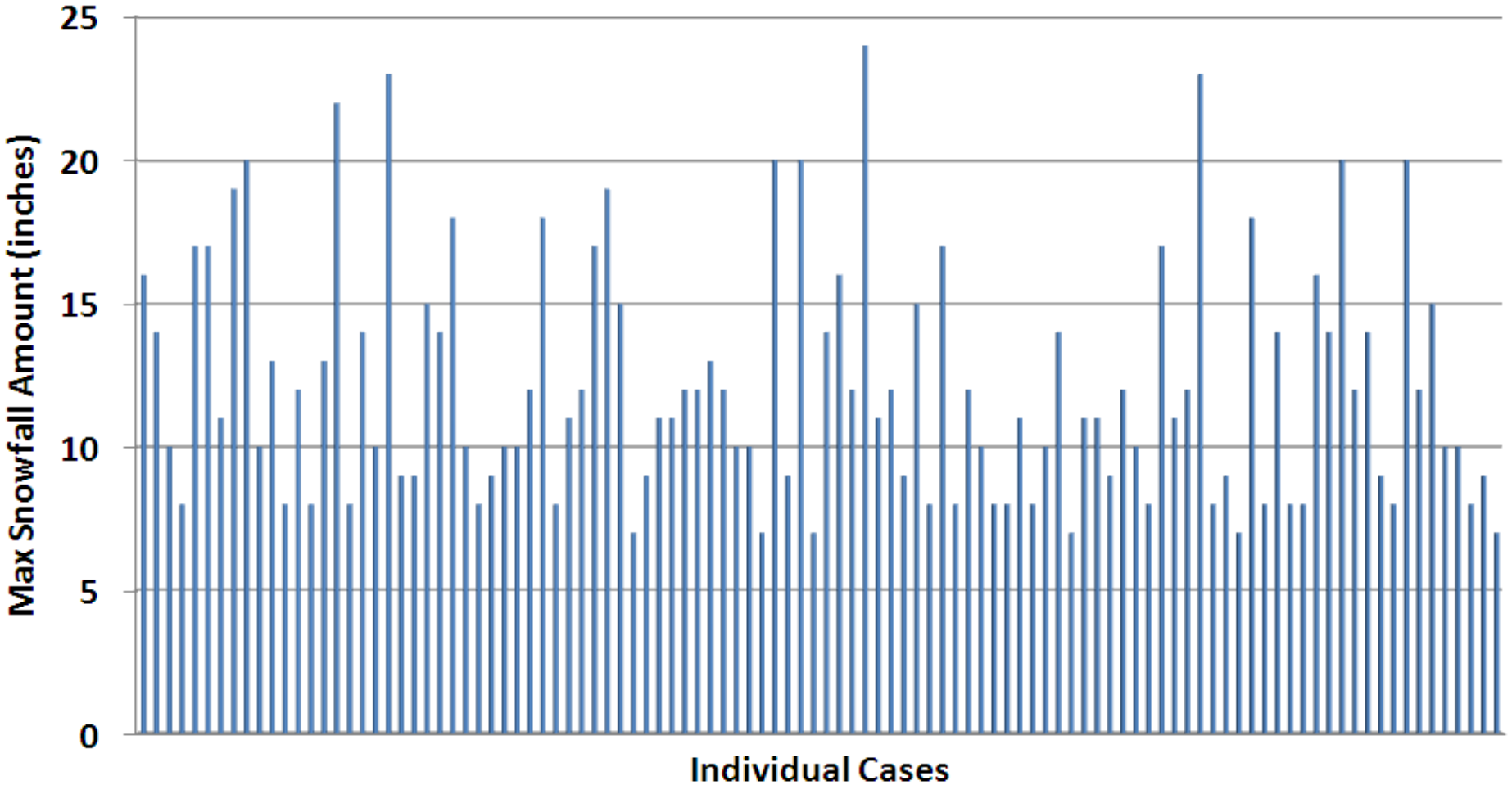
NW Cases Max Snowfall Amount



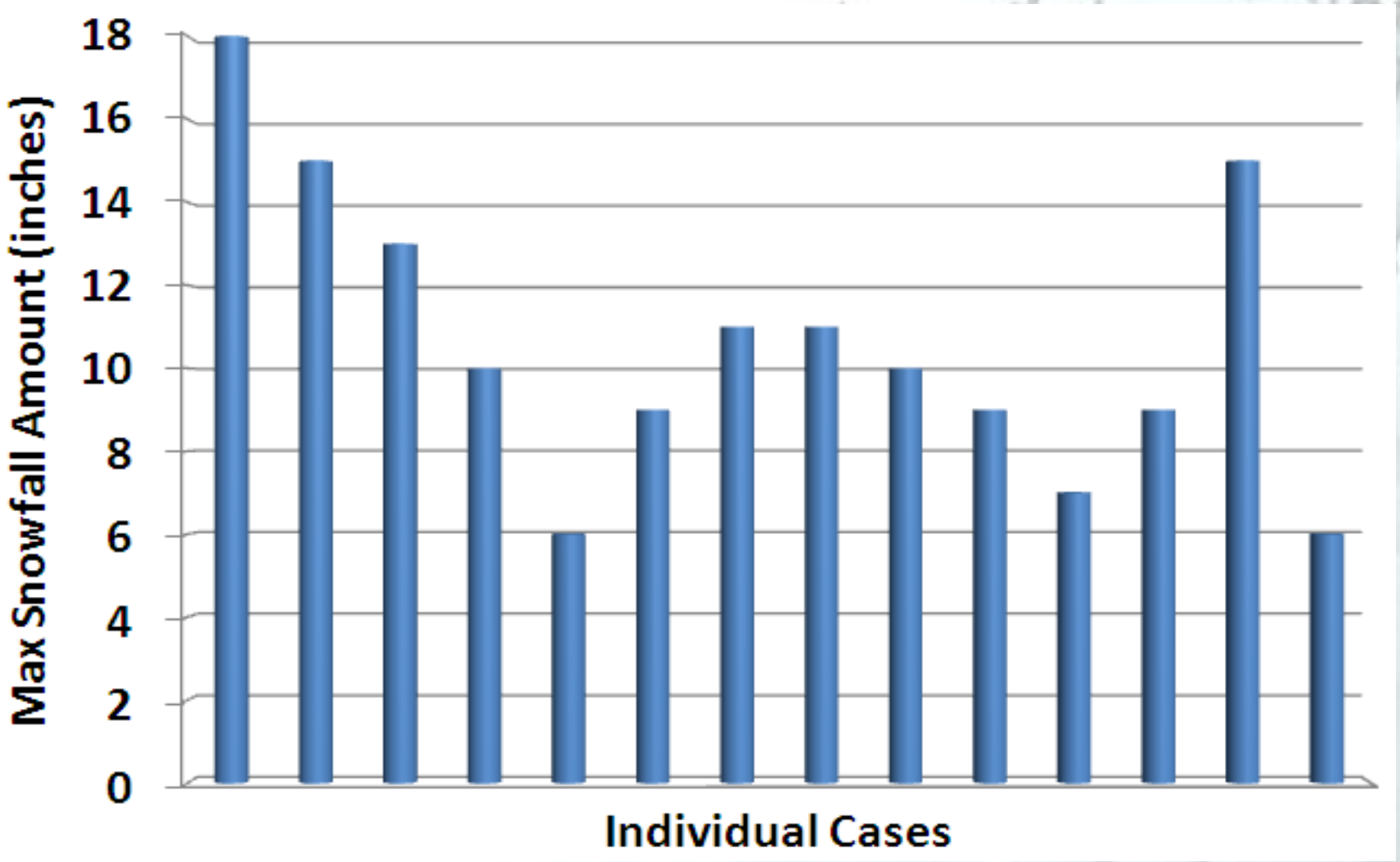
Max Snowfall Amount: All Cases



Max Snowfall Amount: Southwest Cases



Max Snowfall Amount: Northwest Cases

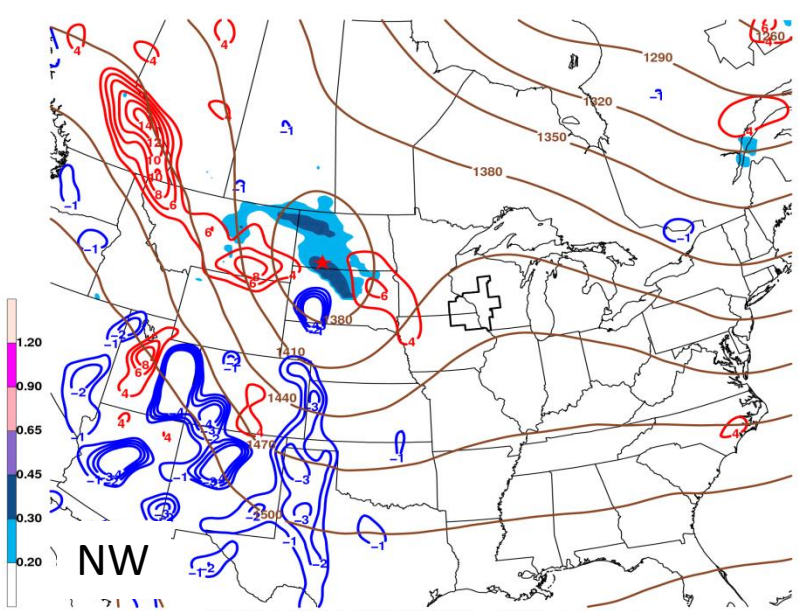


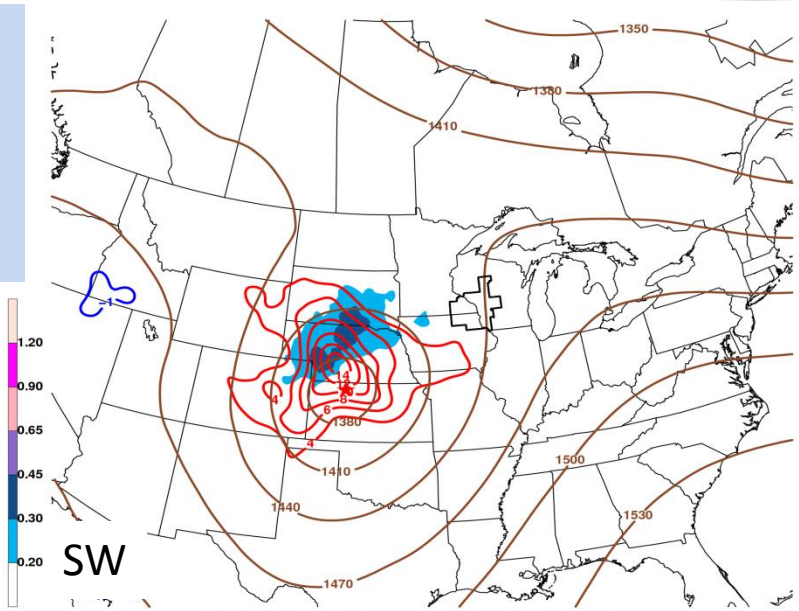

To the composites!

- The slides are broken down by time:
  - T-6 hrs prior to heavy snow period.
  - 12 hour heavy snow period:
    - 00h – Heavy Snow Onset
    - 06h – Heavy Snow
    - 12h – Heavy Snow Ending
  - T+6 hrs after heavy snow period.

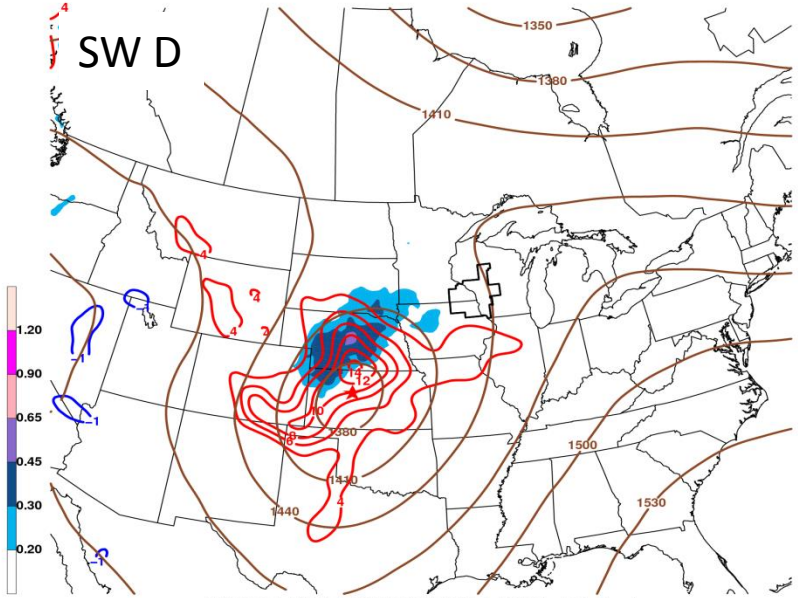
- The slides are broken down by low track:
  - SW D – Southwest flow, Deepening
  - SW SS/W – Southwest flow, Steady-state or Weakening
  - NW – Northwest Flow

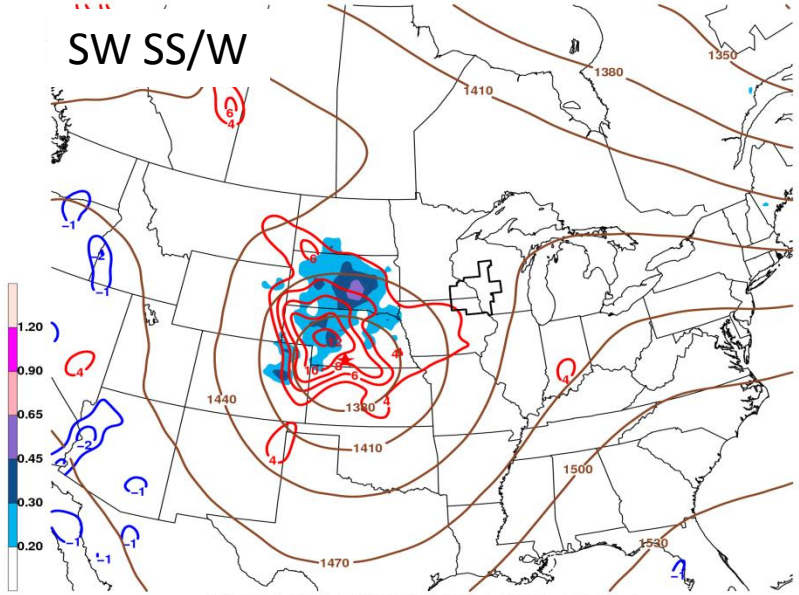
Time: t-6hrs Heavy Snow Begin





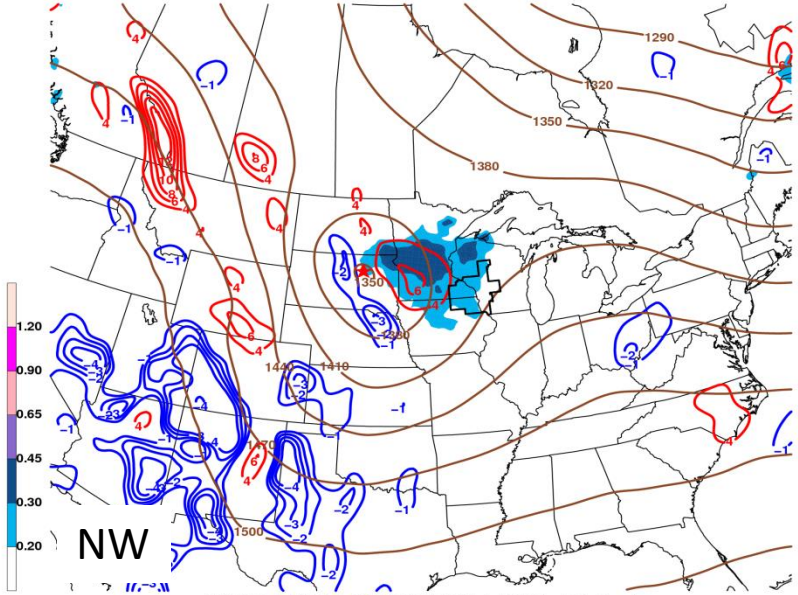
850mb Heights, **Snow Region**

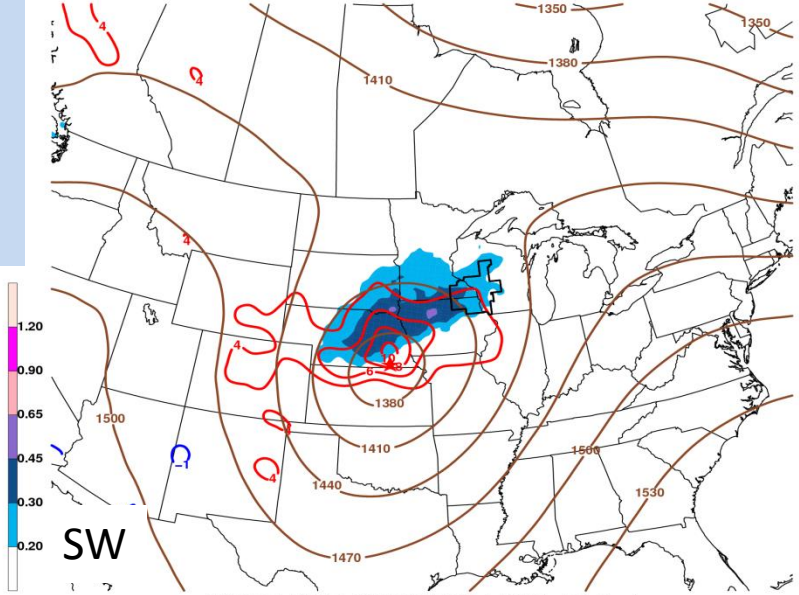




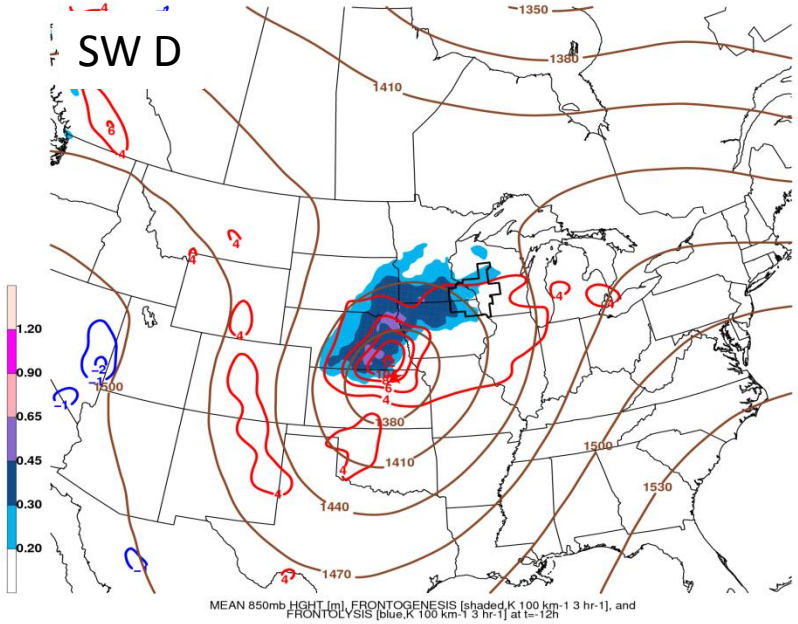
850mb Low indicated by "★"

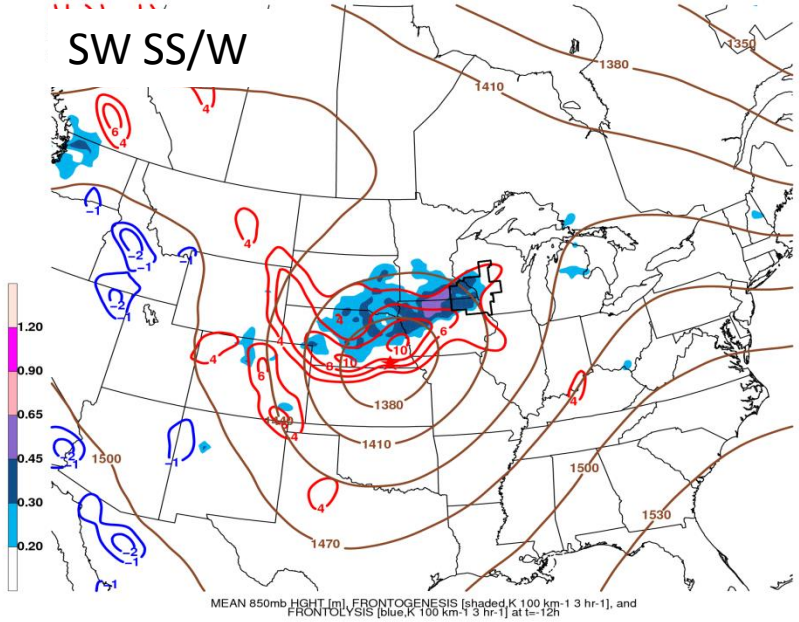
Time: Heavy Snow Begin (00h)





850mb Heights, **Snow Region**

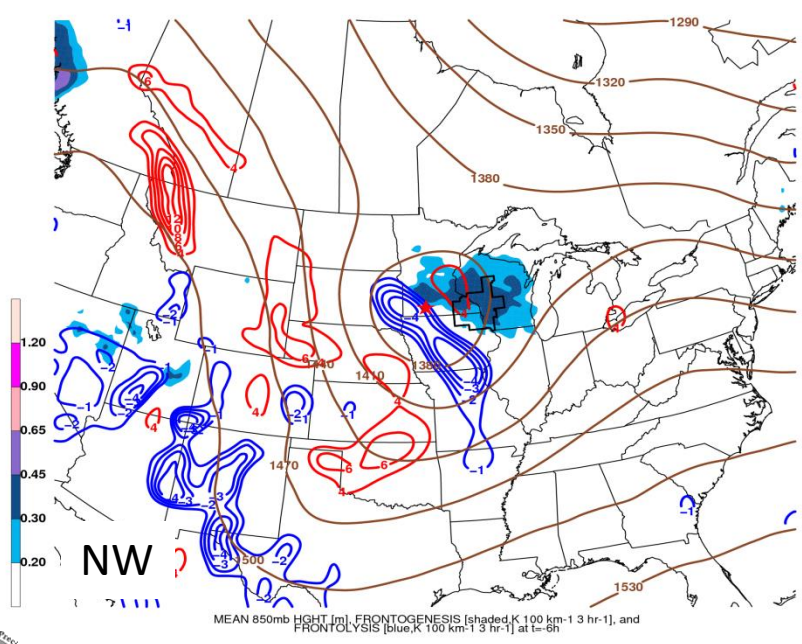


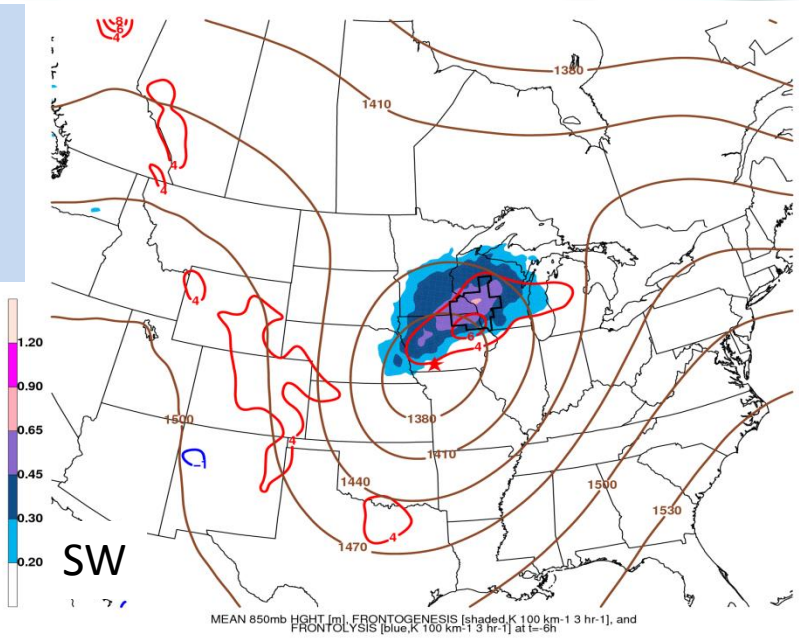


850mb Low indicated by "★"

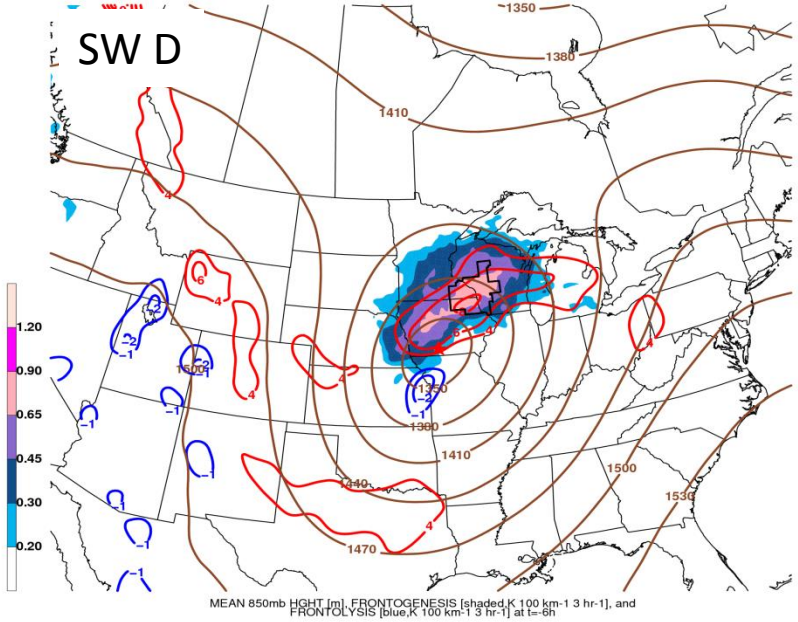
Time: Heavy Snow

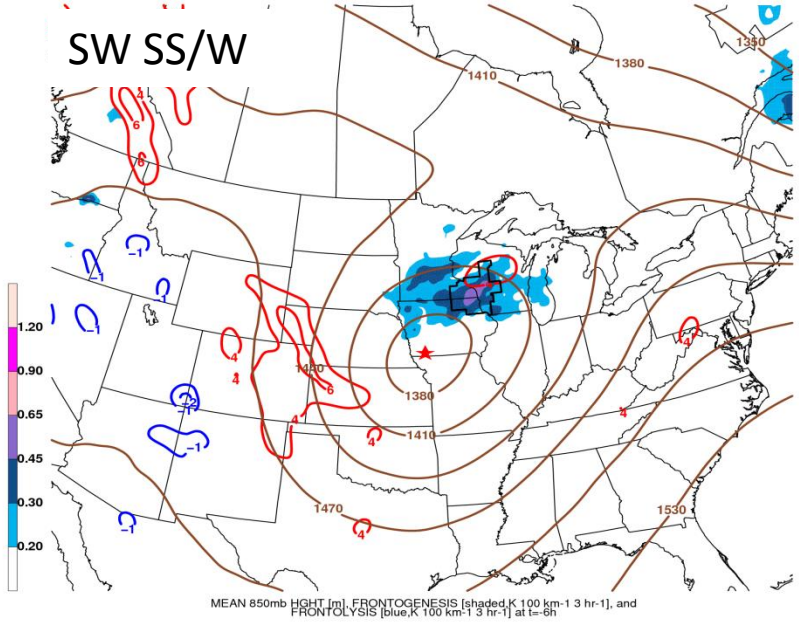
(06h)





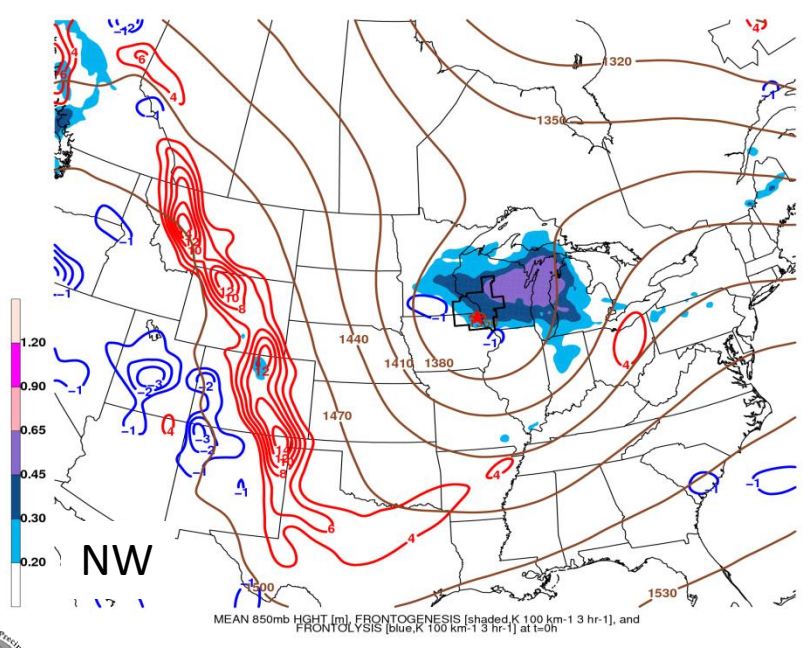
850mb Heights, **Snow Region**

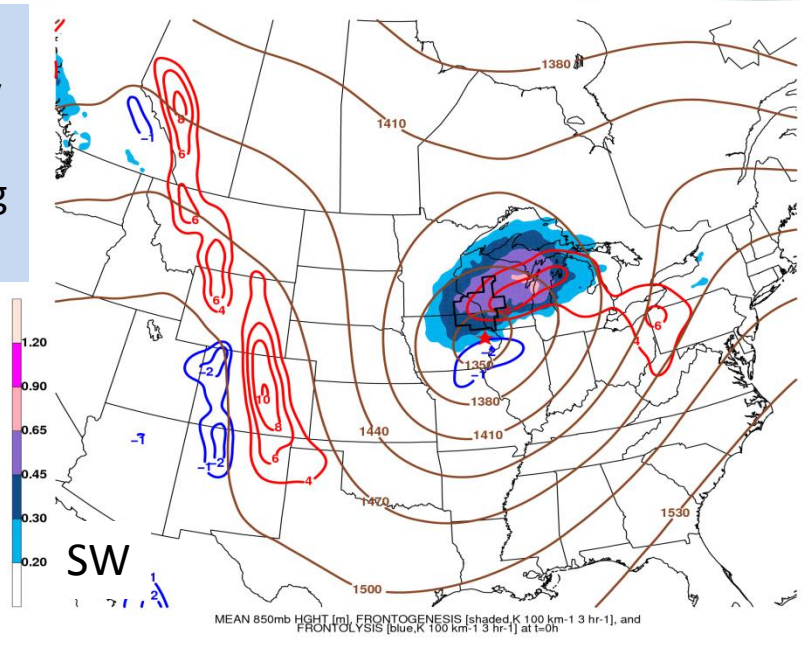




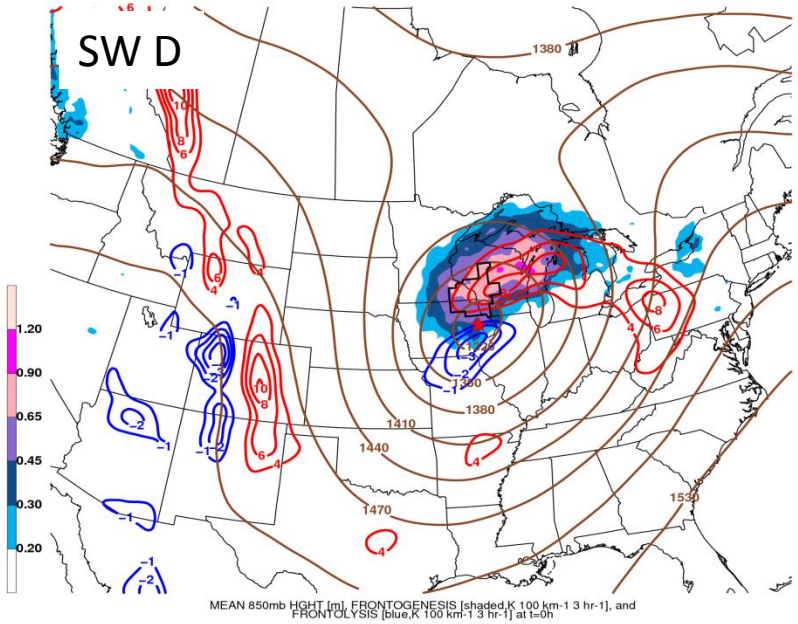
850mb Low indicated by "★"

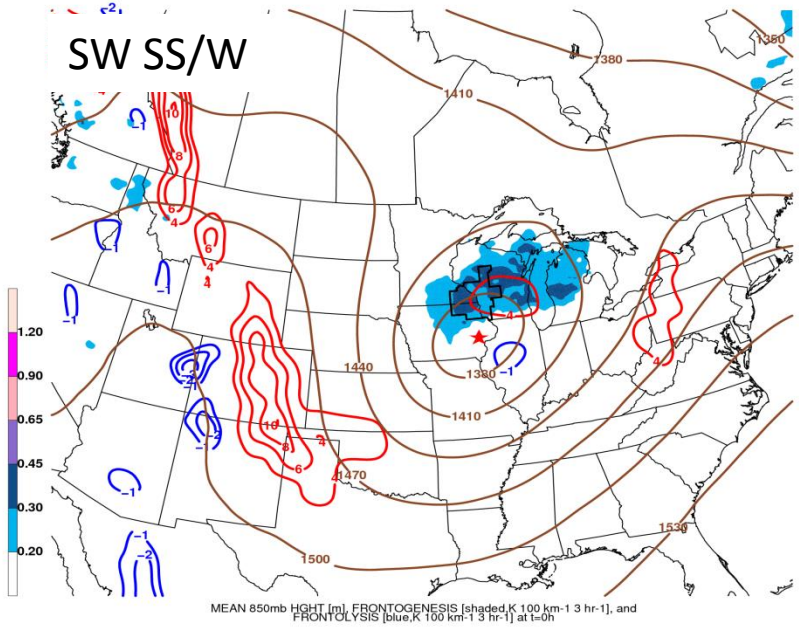
Time: Heavy Snow Ending (12h)





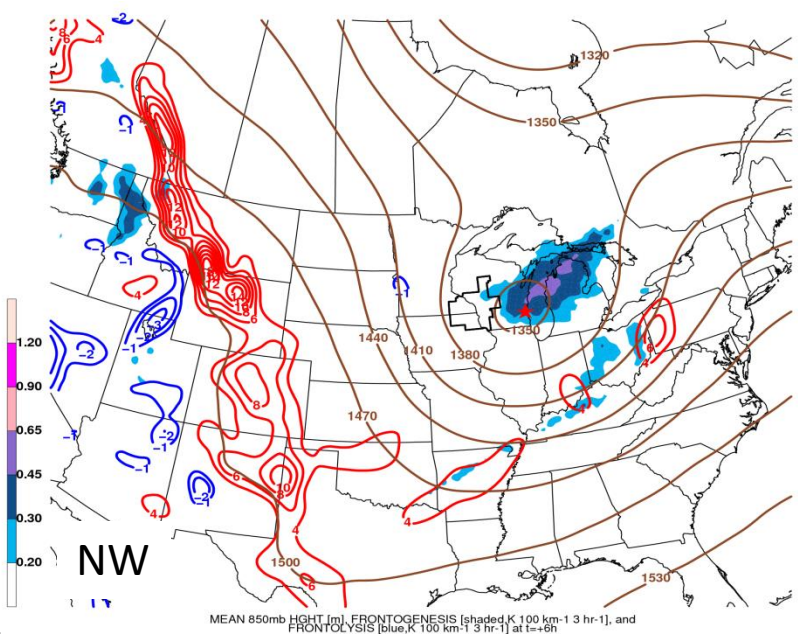
850mb Heights, **Snow Region**

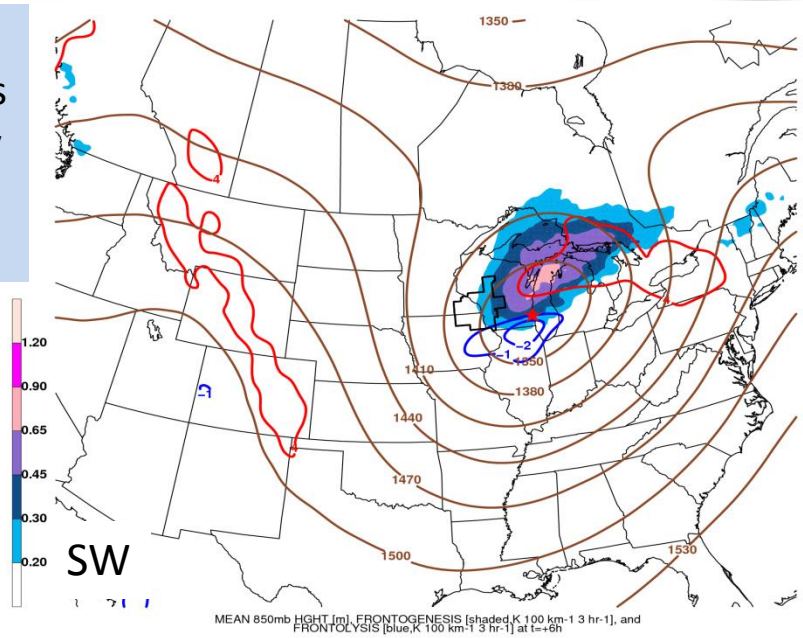




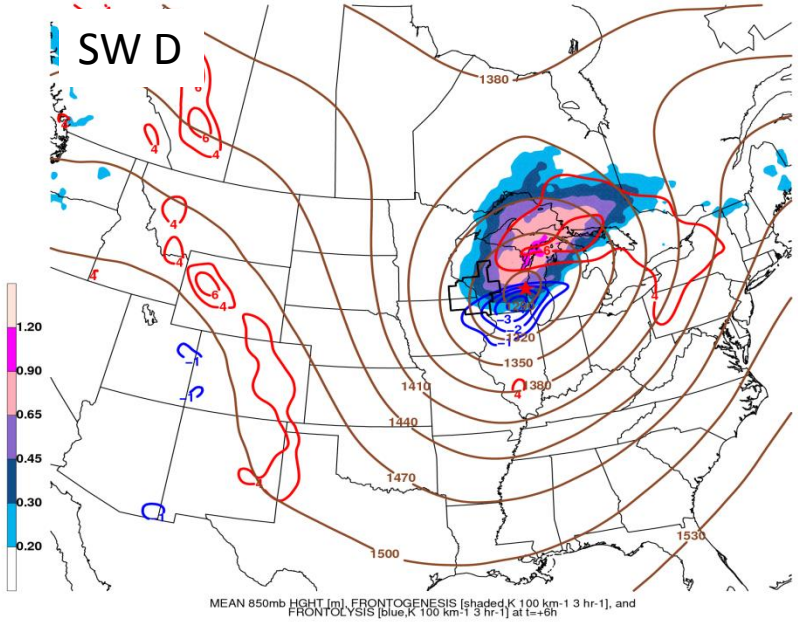
850mb Low indicated by "★"

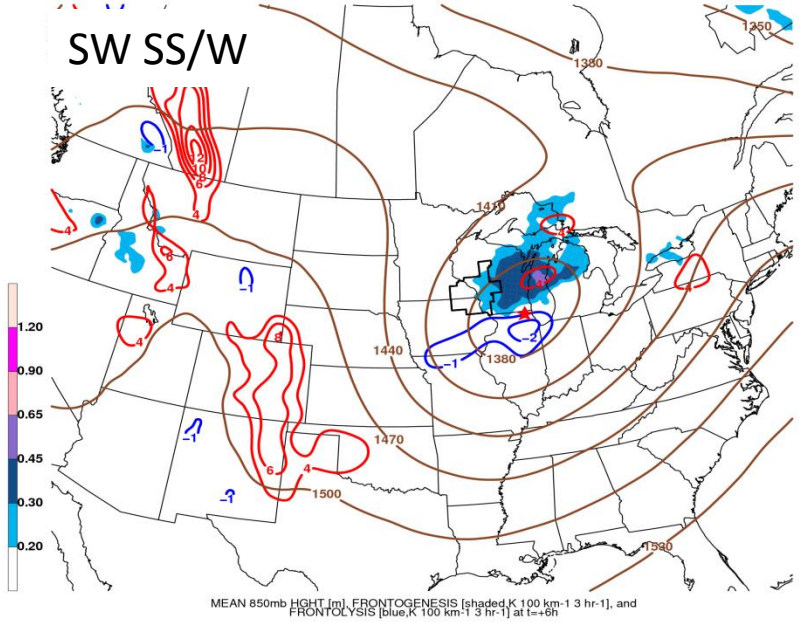
Time:
T+6hrs
Heavy
Snow
End





850mb Heights, Snow Water Equiv, Frontogenesis and Frontolysis





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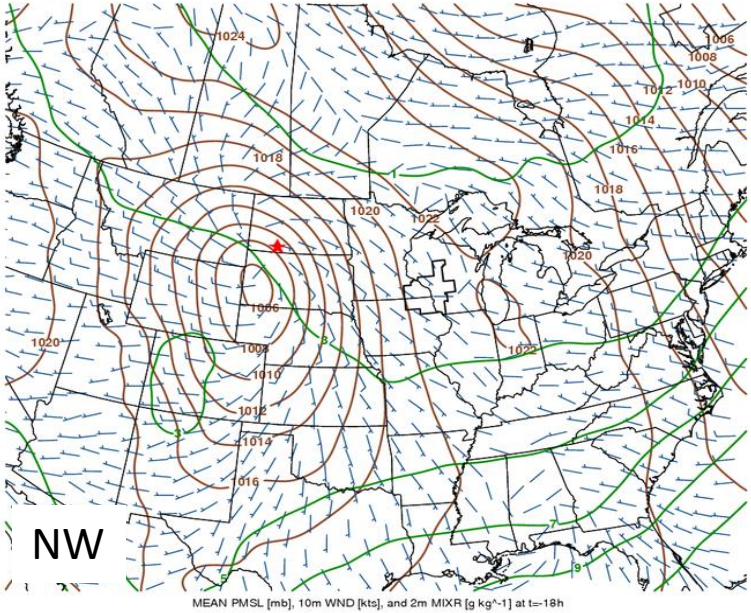
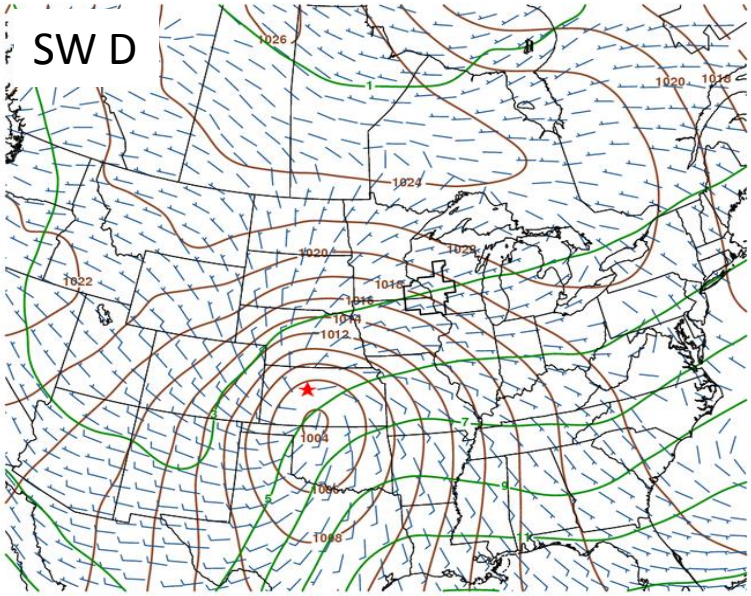
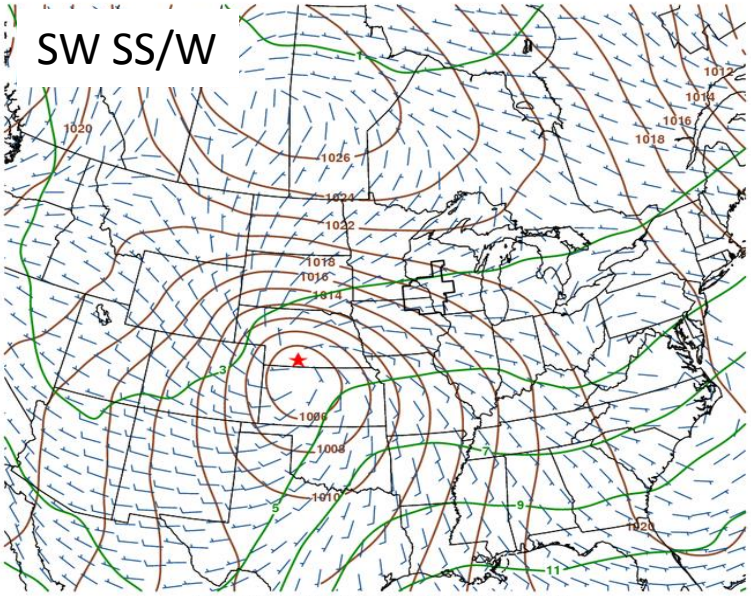


Time:
t-6hrs
Heavy
Snow
Begin

- NW low weakening (filling as it approaches)

MSLP, Winds, Mixing Ratio

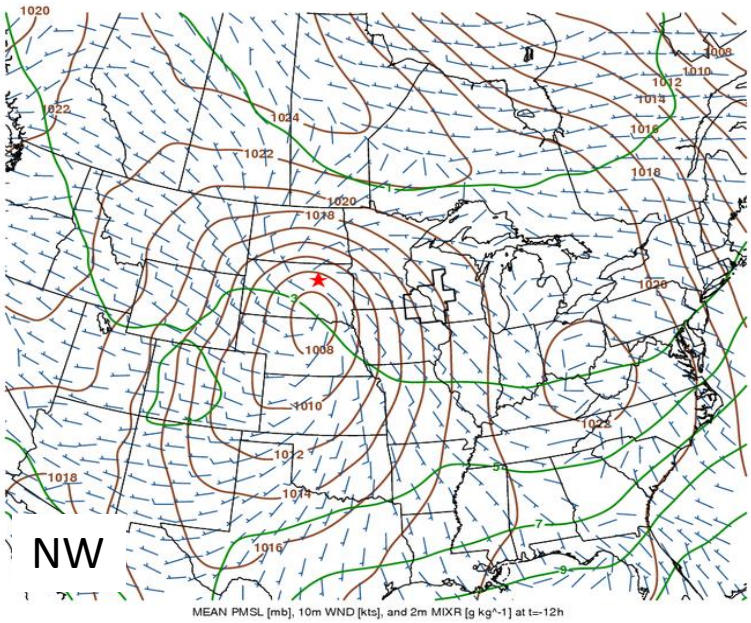




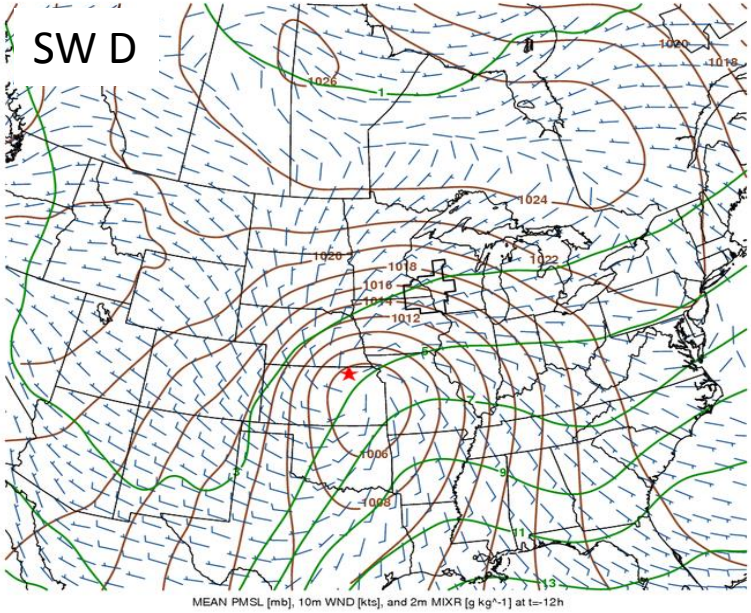
850mb Low indicated by "★"

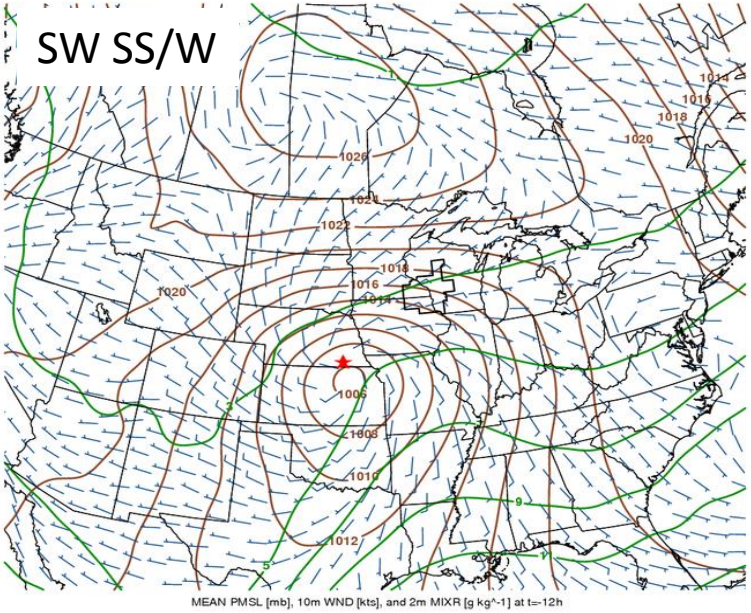
Time: Heavy Snow Begin (00h)

- NW low weakening (filling as it approaches)



MSLP, Winds, Mixing Ratio



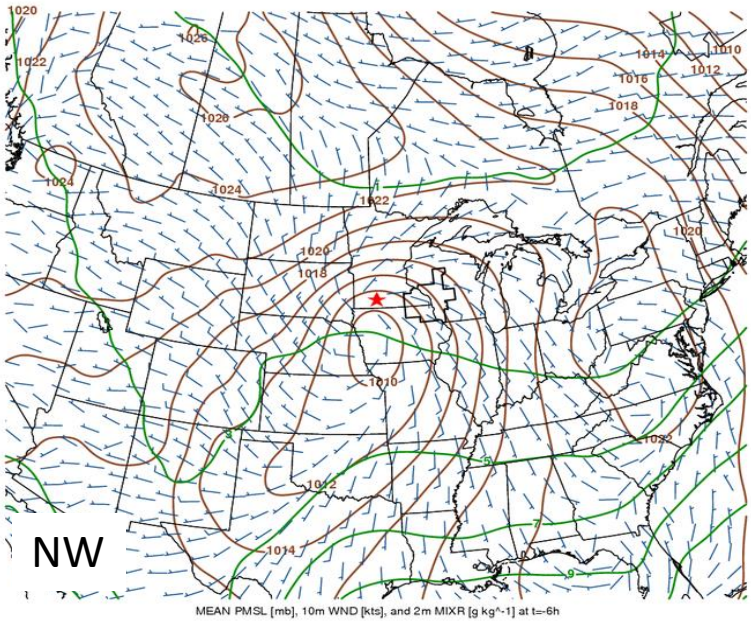


850mb Low indicated by "★"

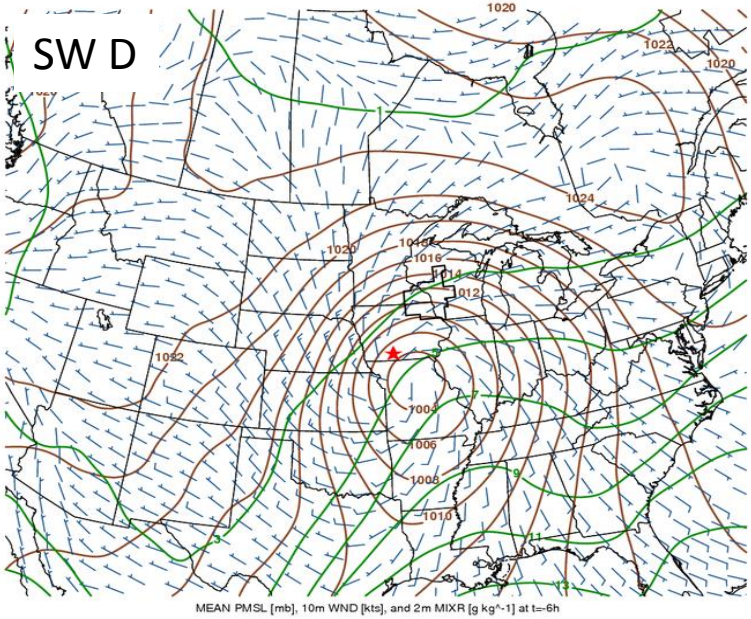
Time: Heavy Snow

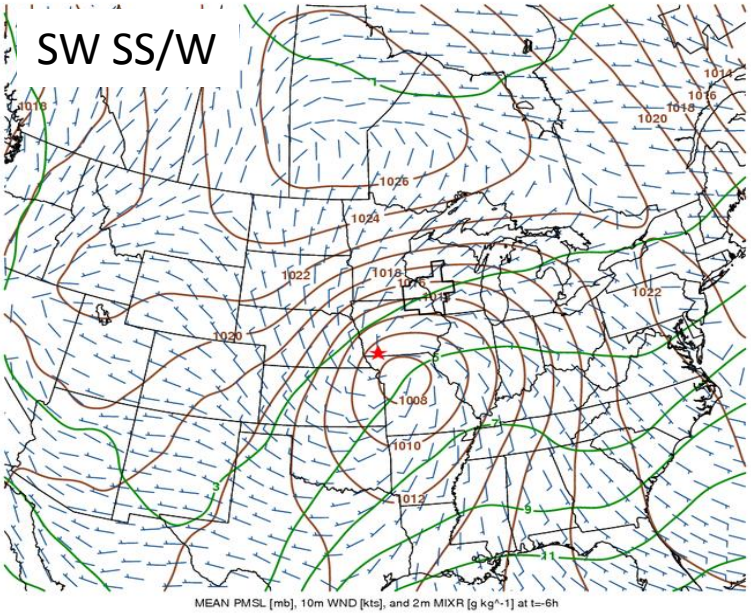
(06h)

- NW low weakening (filling as it approaches)



MSLP, Winds, Mixing Ratio





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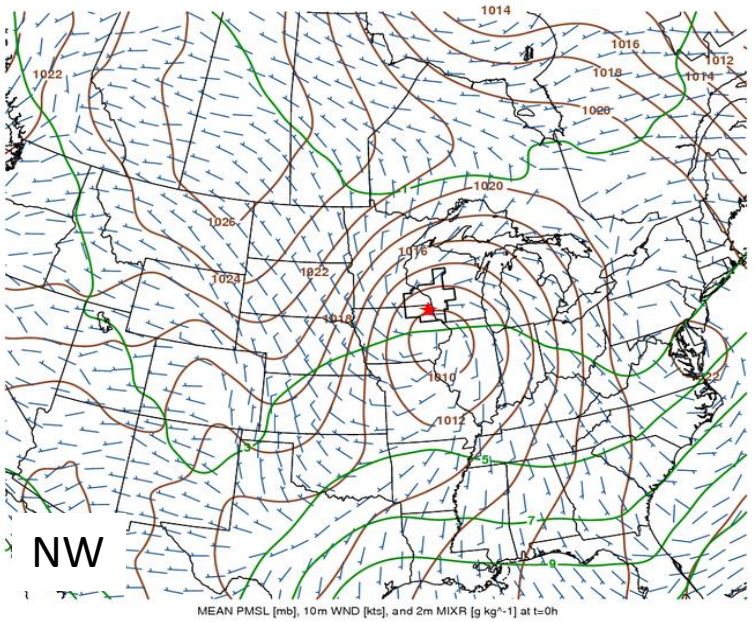
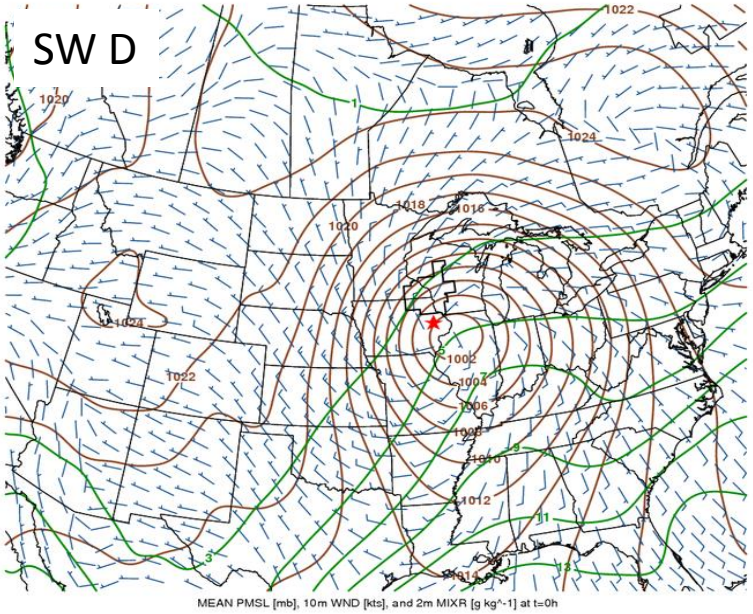
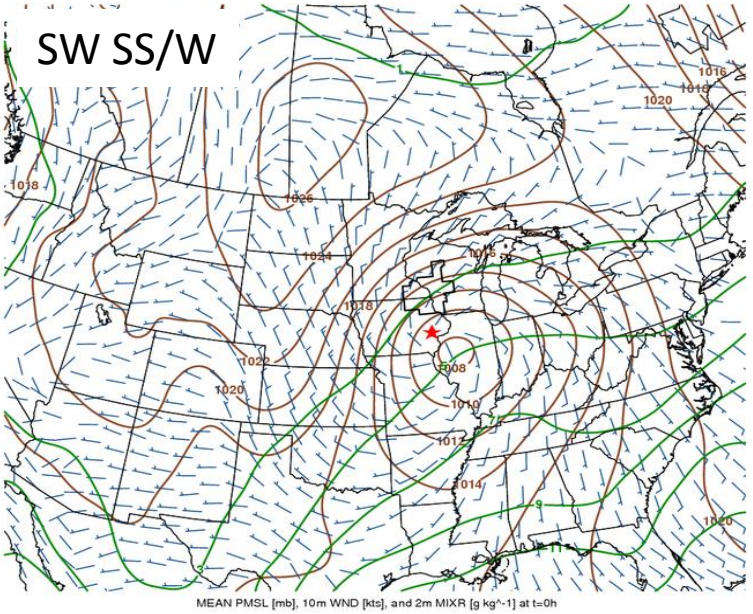


Time: Heavy Snow Ending (12h)

- NW low weakening (filling as it approaches)

MSLP, Winds, Mixing Ratio

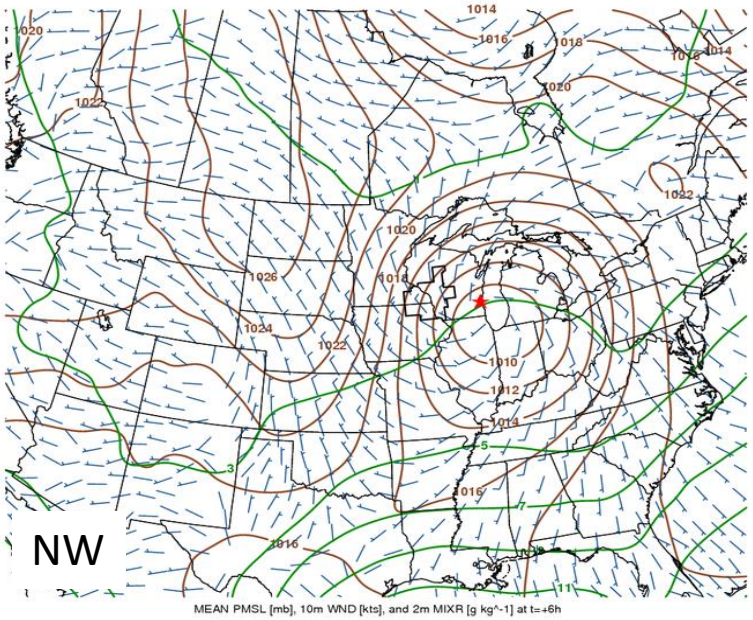




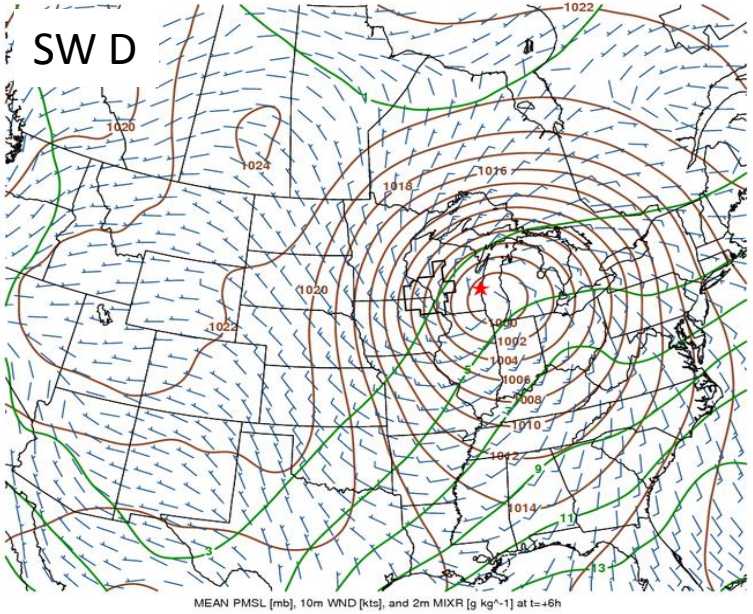
850mb Low indicated by "★"

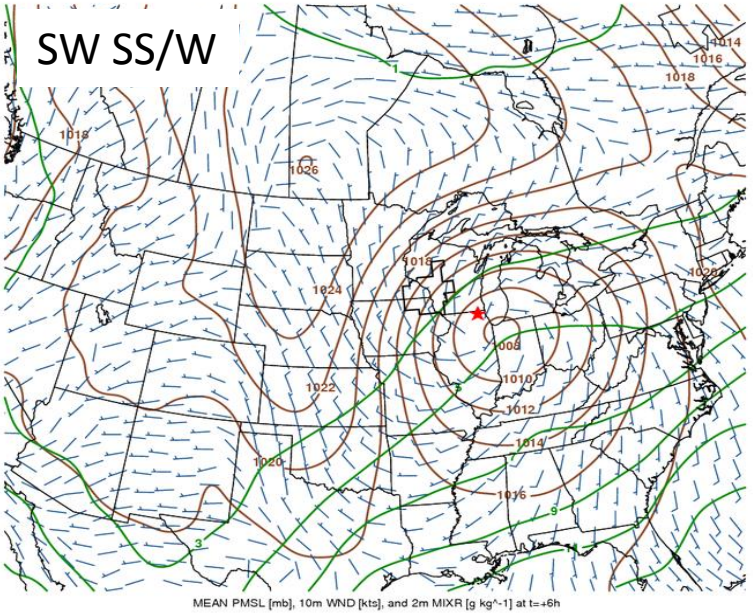
Time:
T+6hrs
Heavy
Snow
End

- NW low weakening (filling as it approaches)



MSLP, Winds, Mixing Ratio





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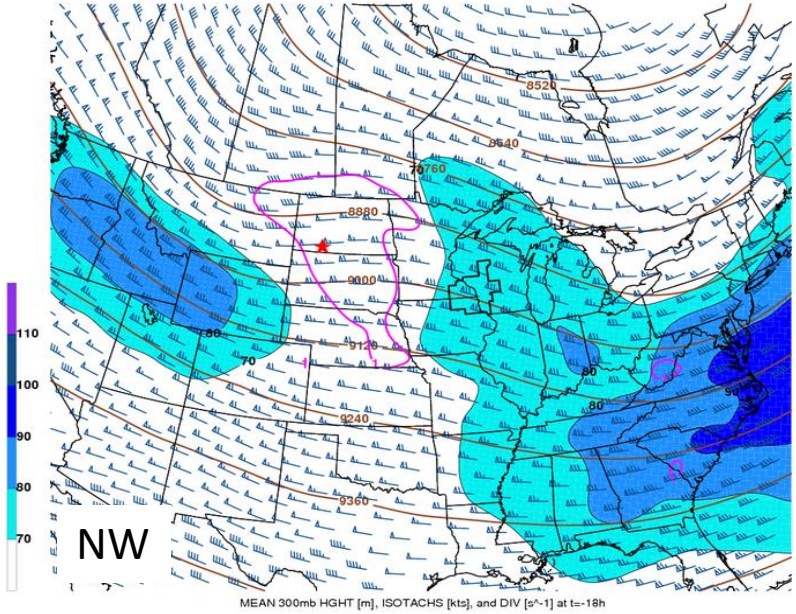
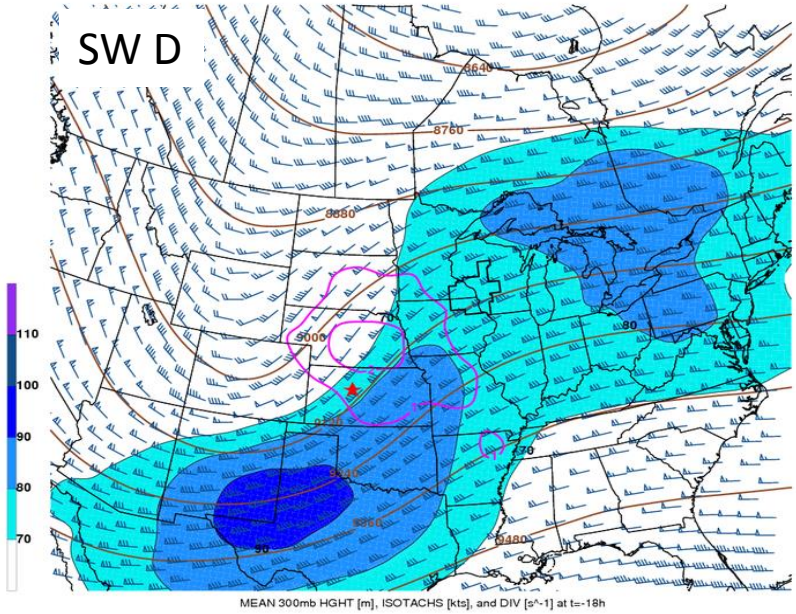
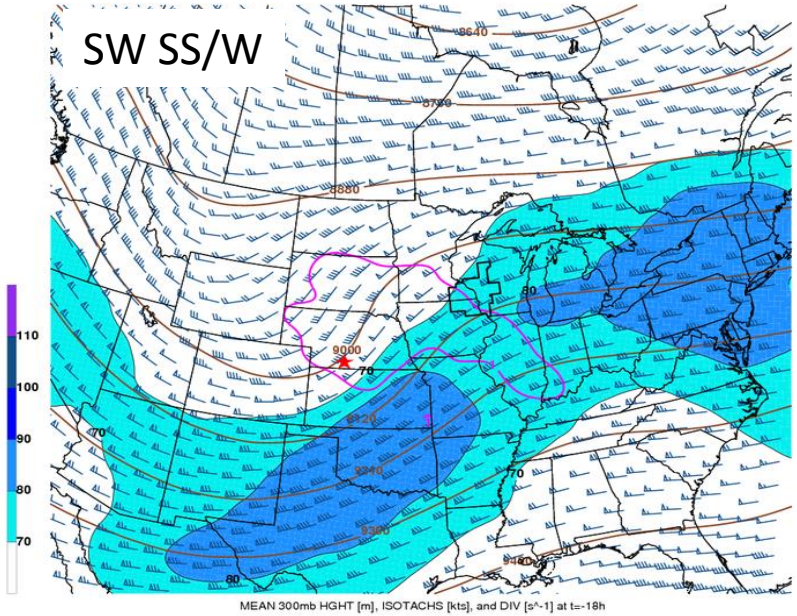


Time: t-6hrs Heavy Snow Begin

- NW: Broad lift due to curvature effects.
- SW: Coupled jet. Nrn jet increases as ridge builds.
- SW: Mesoscale forcing from along-stream speed change effects.

300mb Heights, Winds, **Isotachs (kts)**, Divergence (s^{-1})

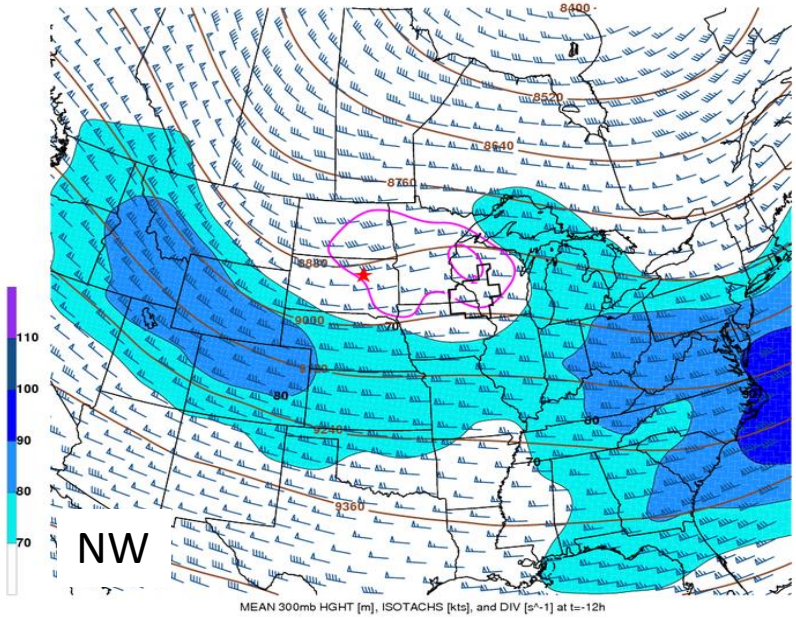




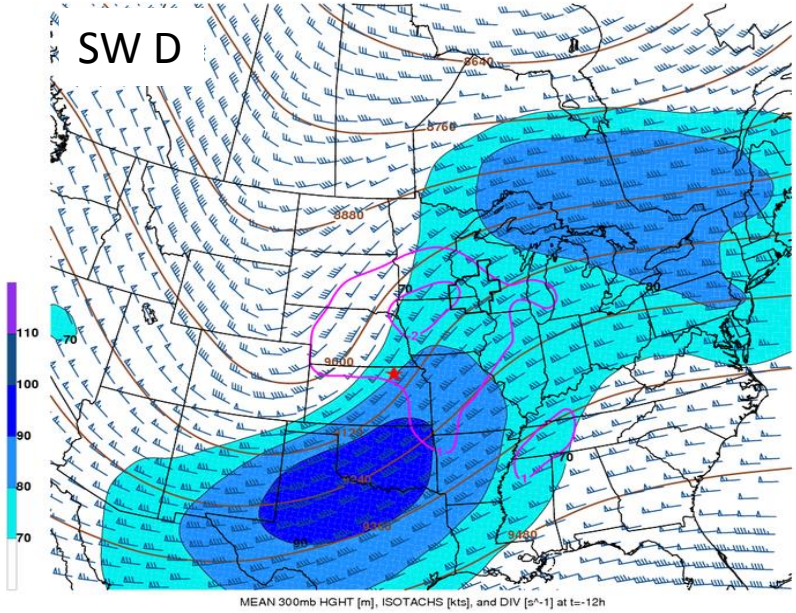
850mb Low indicated by "★"

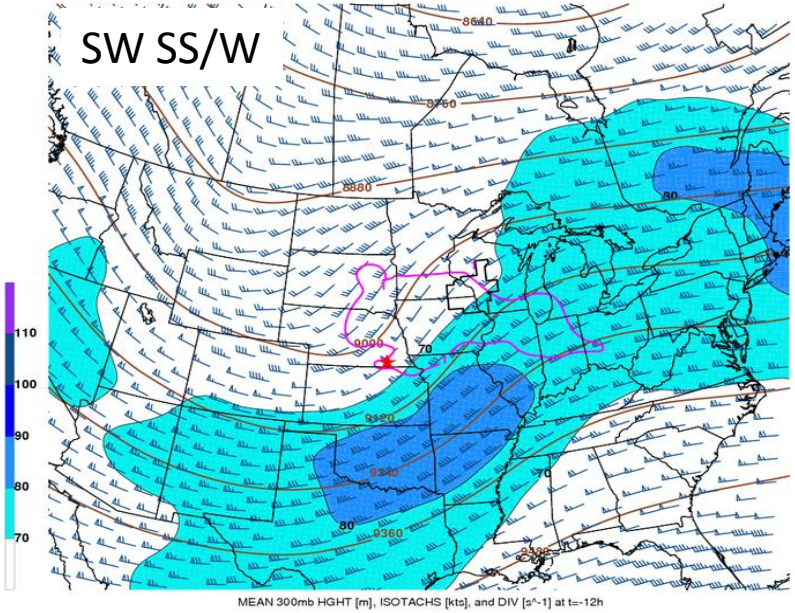
Time: Heavy Snow Begin (00h)

- NW: Broad lift due to curvature effects.
- SW: Coupled jet. Nrn jet increases as ridge builds.
- SW: Mesoscale forcing from along-stream speed change effects.



300mb Heights, Winds, **Isotachs (kts)**, Divergence (s^{-1})





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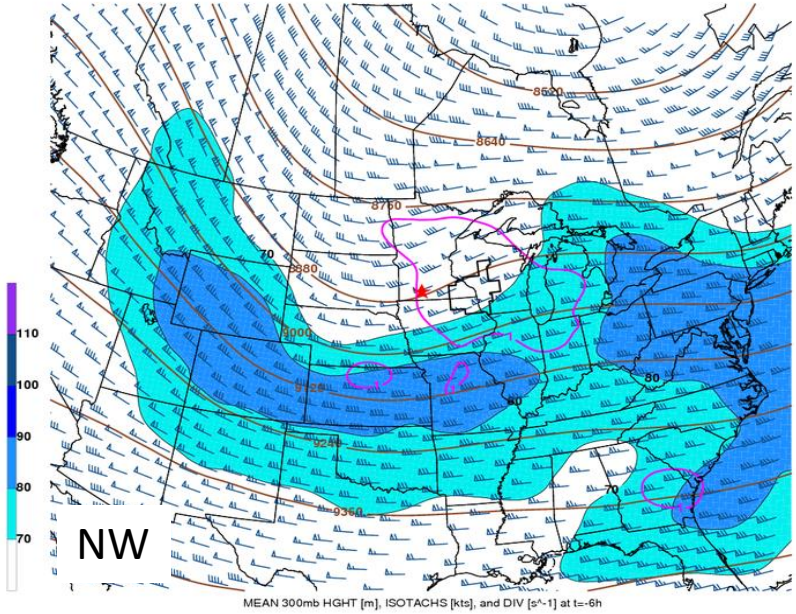
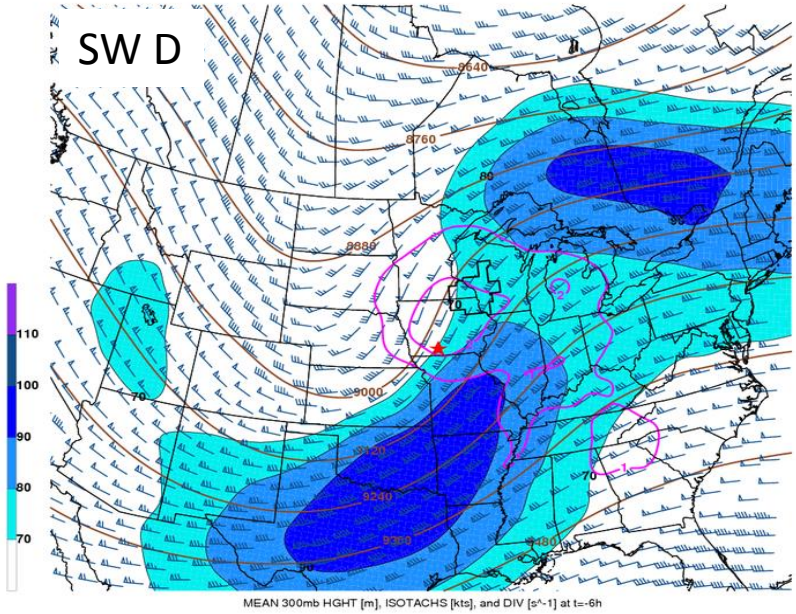


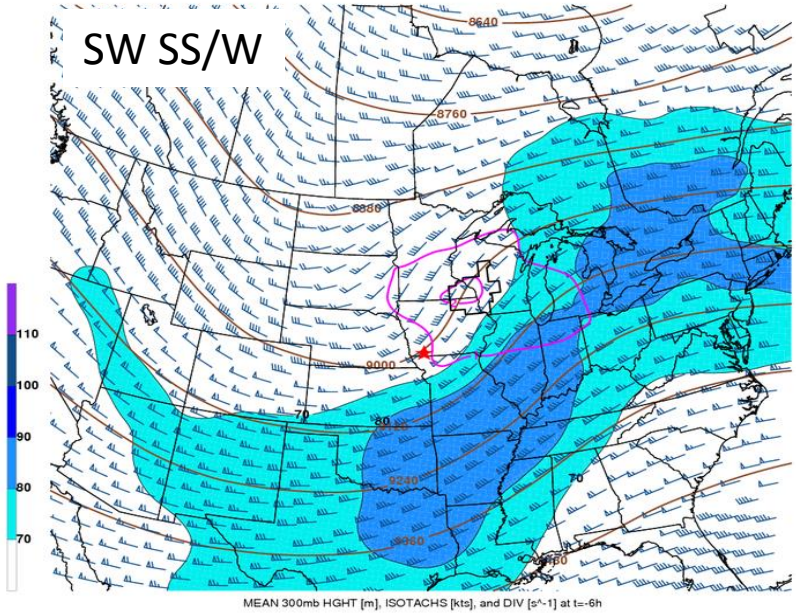
Time: Heavy Snow

(06h)

- NW: Broad lift due to curvature effects.
- SW: Coupled jet. Nrn jet increases as ridge builds.
- SW: Mesoscale forcing from along-stream speed change effects.

300mb Heights, Winds, **Isotachs (kts)**, Divergence (s^{-1})

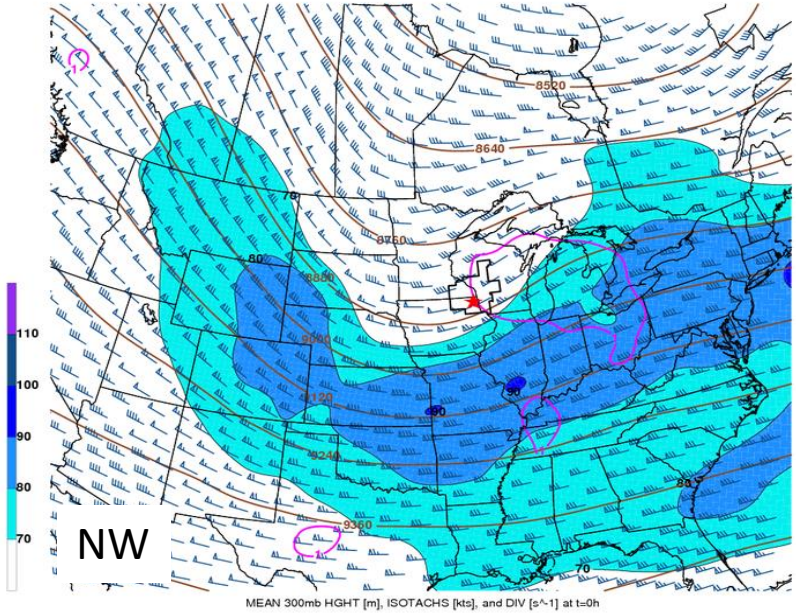




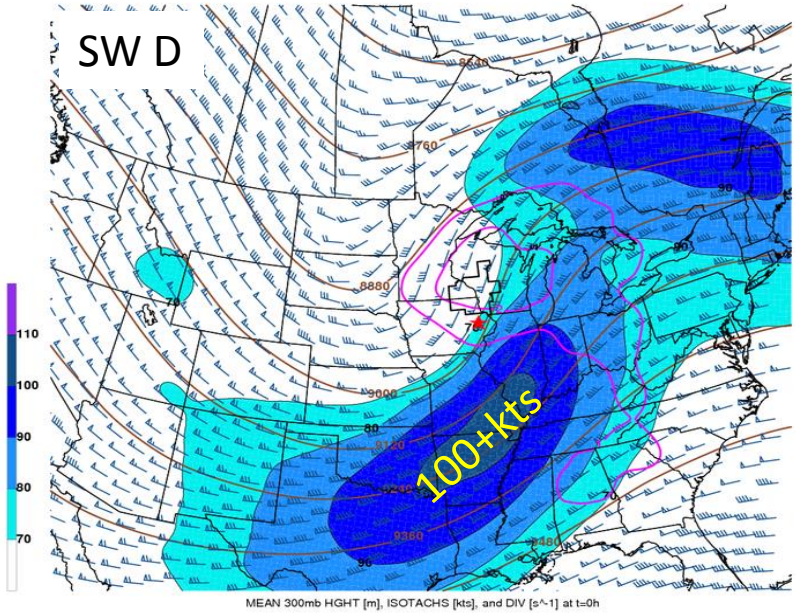
850mb Low indicated by "★"

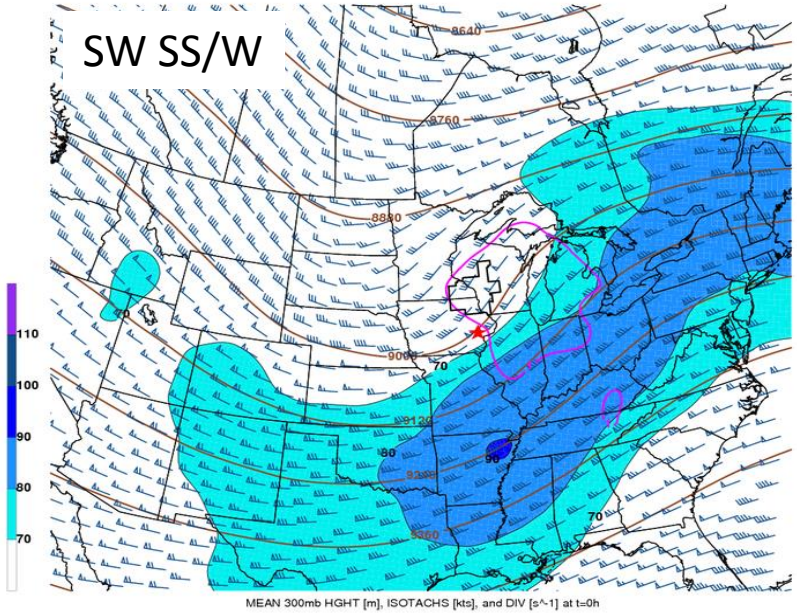
Time: Heavy Snow Ending (12h)

- NW: Broad lift due to curvature effects.
- SW: Coupled jet. Nrn jet increases as ridge builds.
- SW: Mesoscale forcing from along-stream speed change effects.

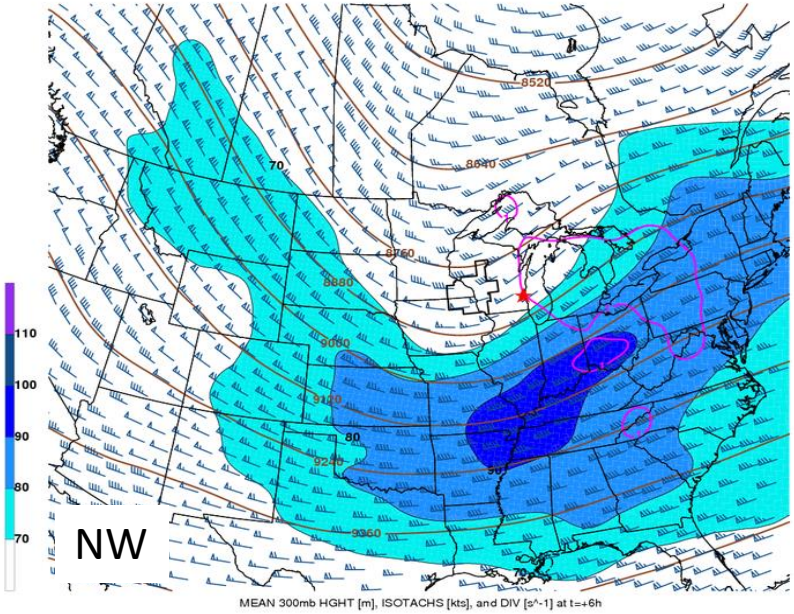


300mb Heights, Winds, **Isotachs (kts)**, Divergence (s^{-1})





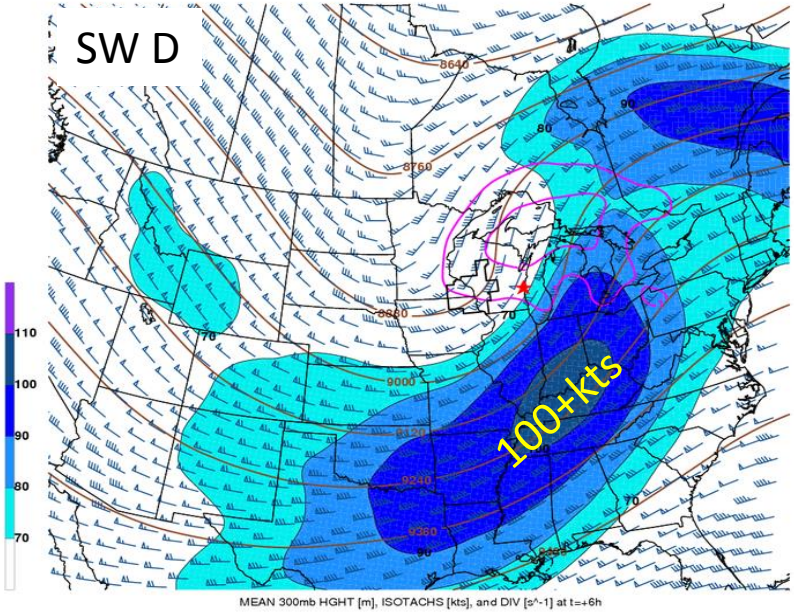
850mb Low indicated by "★"

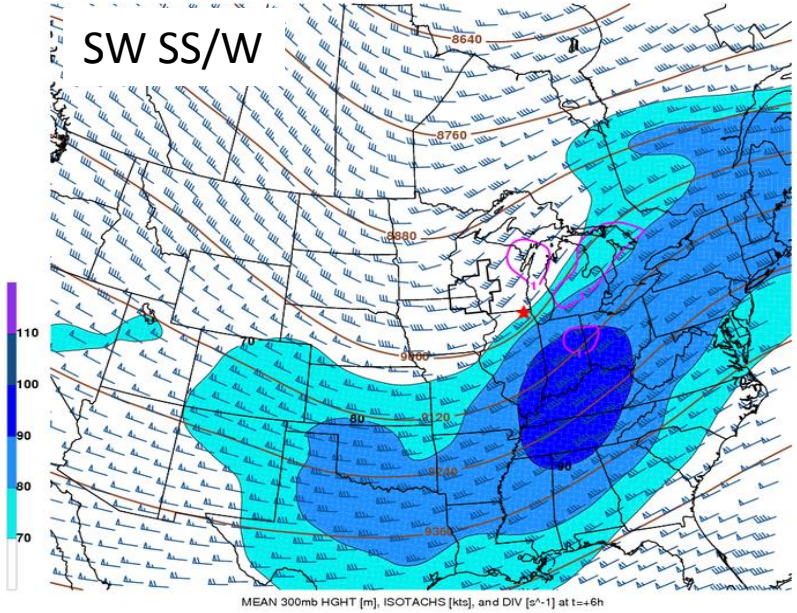


Time:
T+6hrs
Heavy
Snow
End

- NW: Broad lift due to curvature effects.
- SW: Coupled jet. Nrn jet increases as ridge builds.
- SW: Mesoscale forcing from speed change effects.

300mb Heights, Winds, **Isotachs (kts)**, Divergence (s^{-1})



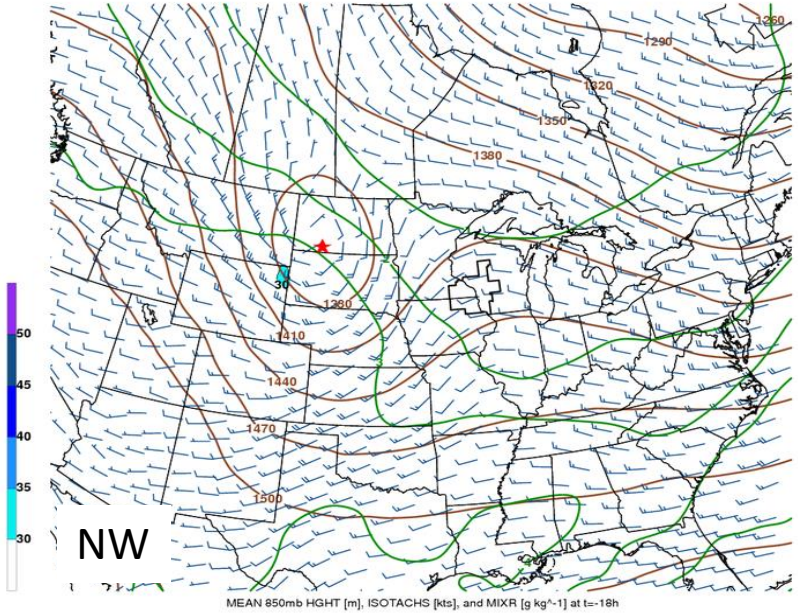


850mb Low indicated by "★"

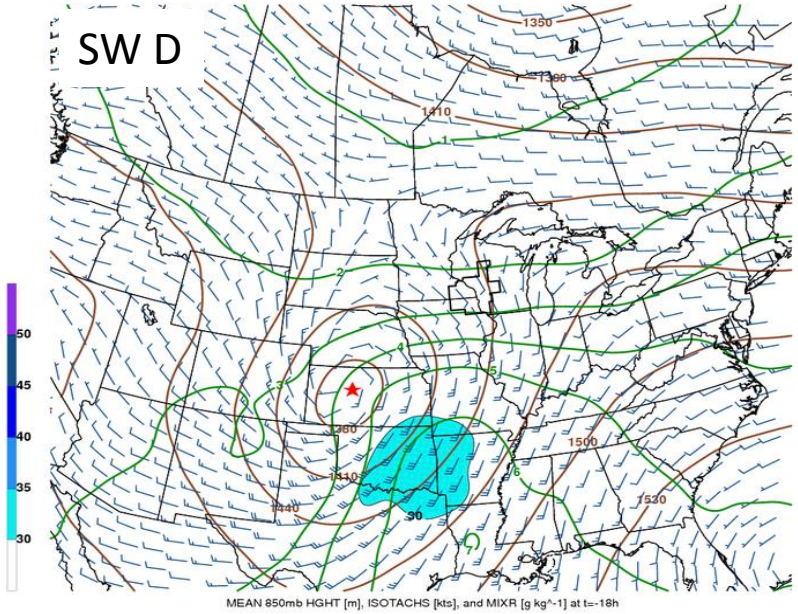
Time:
t-6hrs
Heavy
Snow
Begin

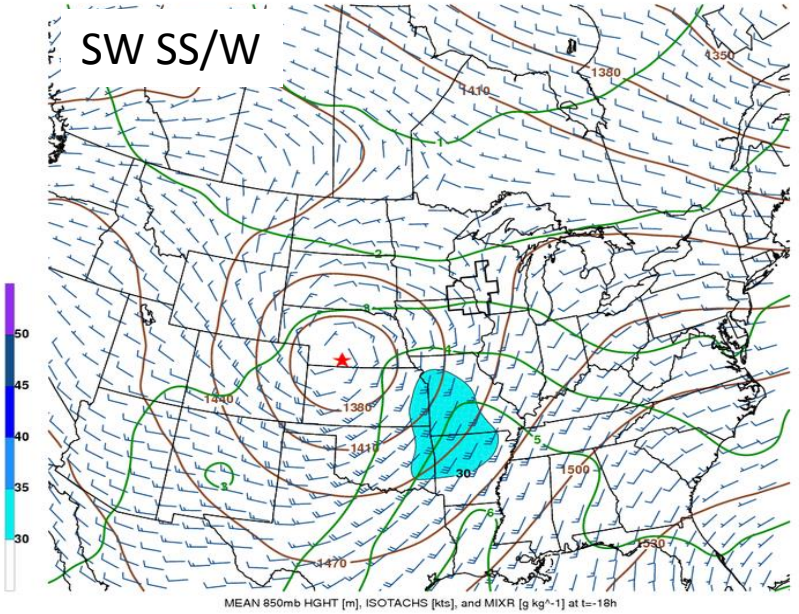
- Wind Max: NW CAA, SW WAA
- Mixing Ratio NW 2-3g/kg, SW 3-4g/kg
- Low Center: NW steady state vs. SW D

~30m falls every 6 hours



850mb Heights, Winds, **Isotachs (kts)**, Mixing Ratio

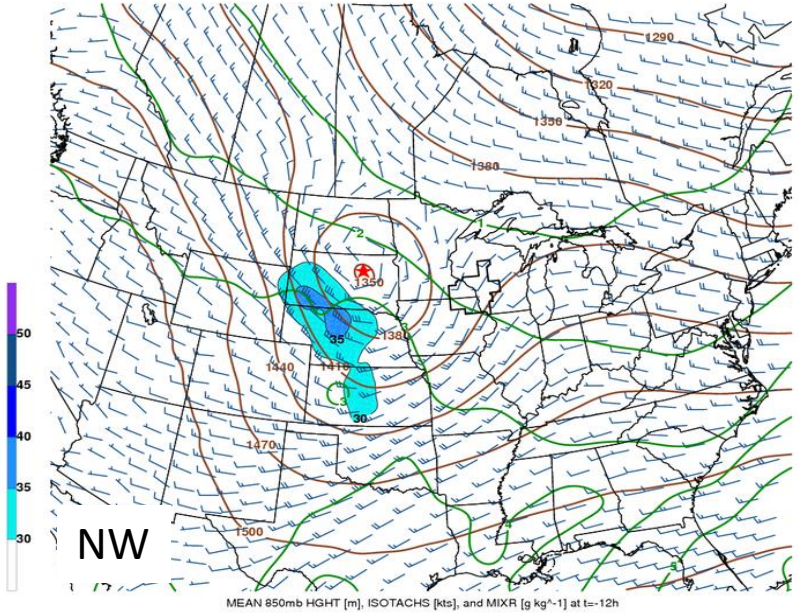




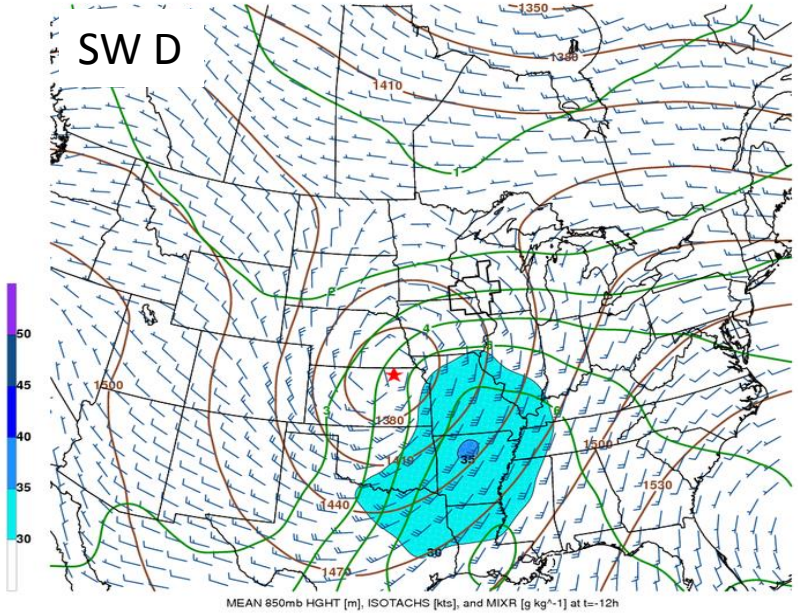
Time: Heavy Snow Begin (00h)

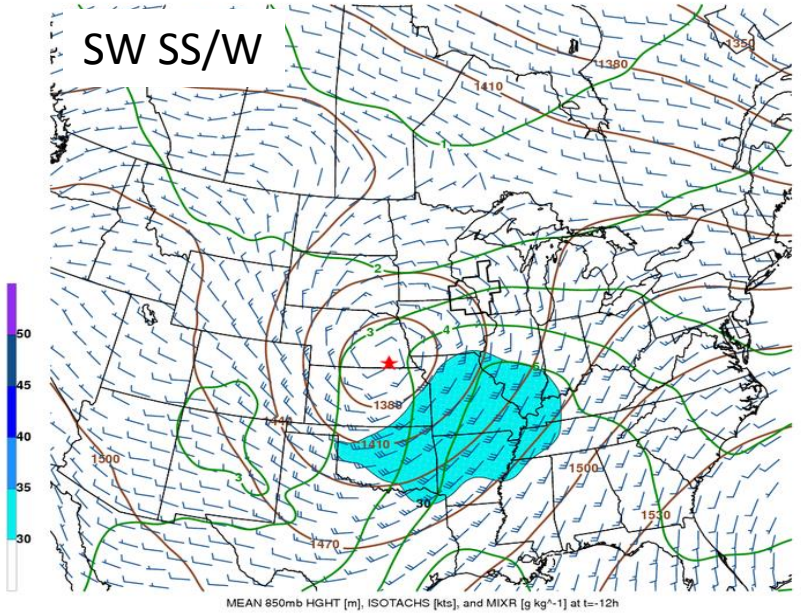
- Wind Max: NW CAA, SW WAA
- Mixing Ratio NW 2-3g/kg, SW 3-4g/kg
- Low Center: NW steady state vs. SW D

~30m falls every 6 hours



850mb Heights, Winds, **Isotachs (kts)**, Mixing Ratio



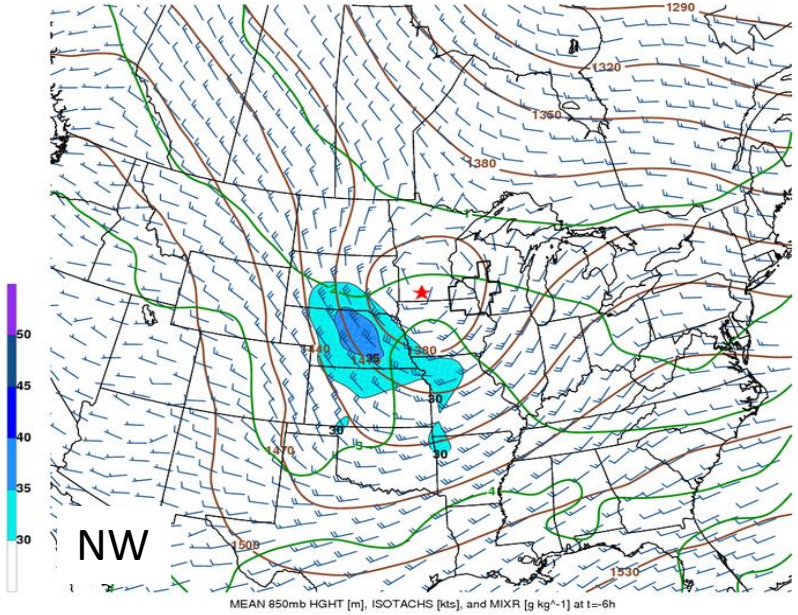


Time:
Heavy
Snow

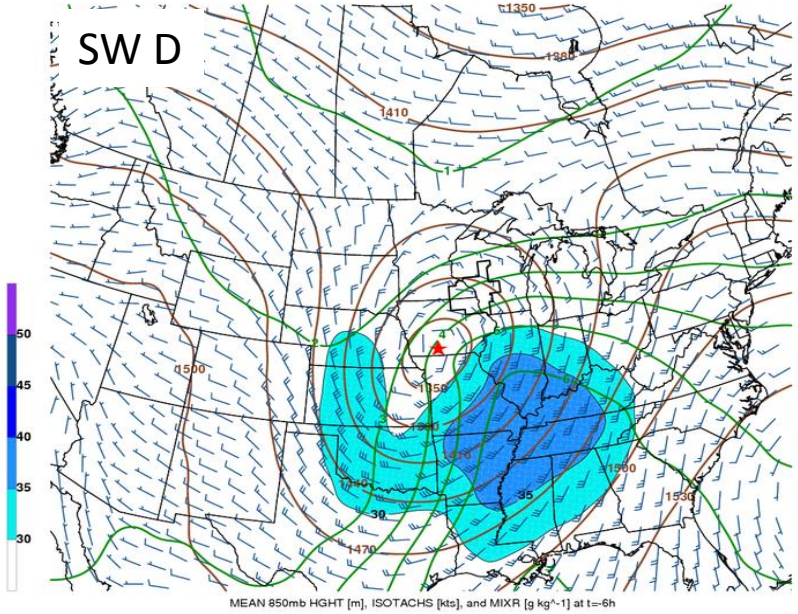
(06h)

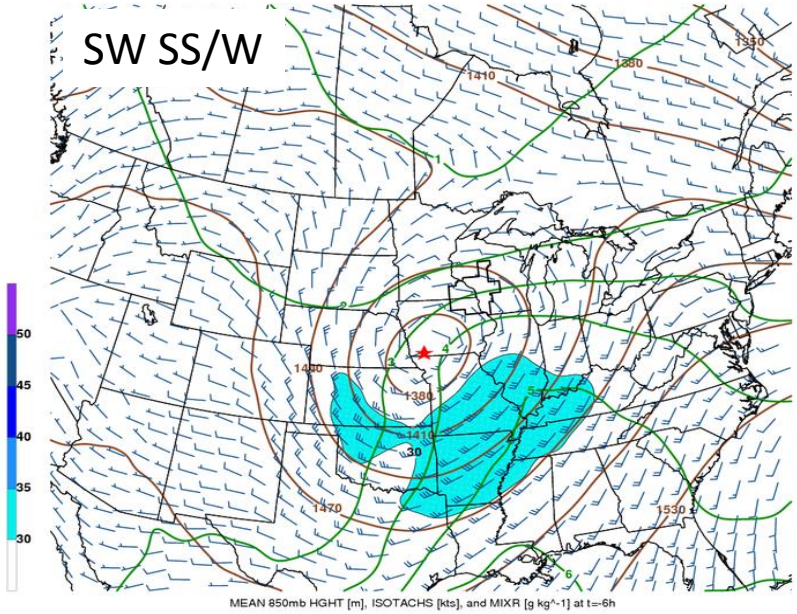
- Wind Max: NW CAA, SW WAA
- Mixing Ratio NW 2-3g/kg, SW 3-4g/kg
- Low Center: NW steady state vs. SW D

~30m falls every 6 hours



850mb Heights, Winds, **Isotachs (kts)**, Mixing Ratio

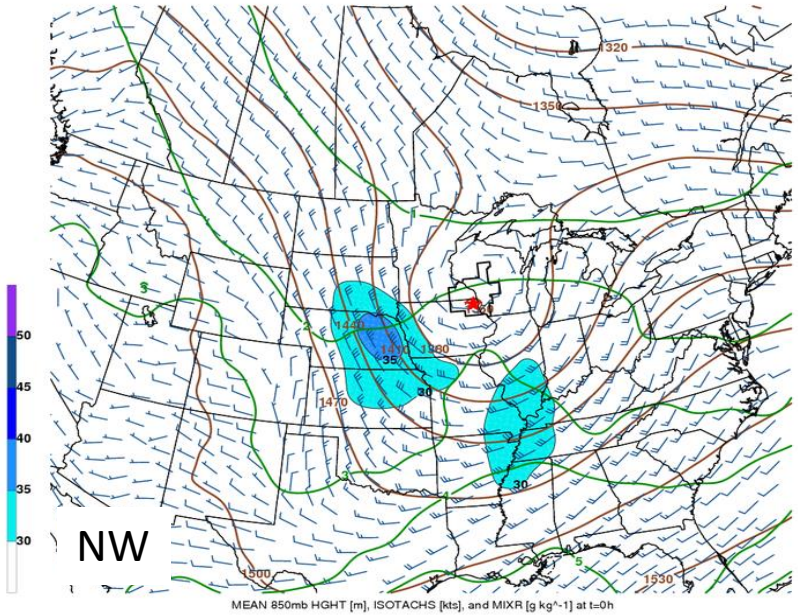




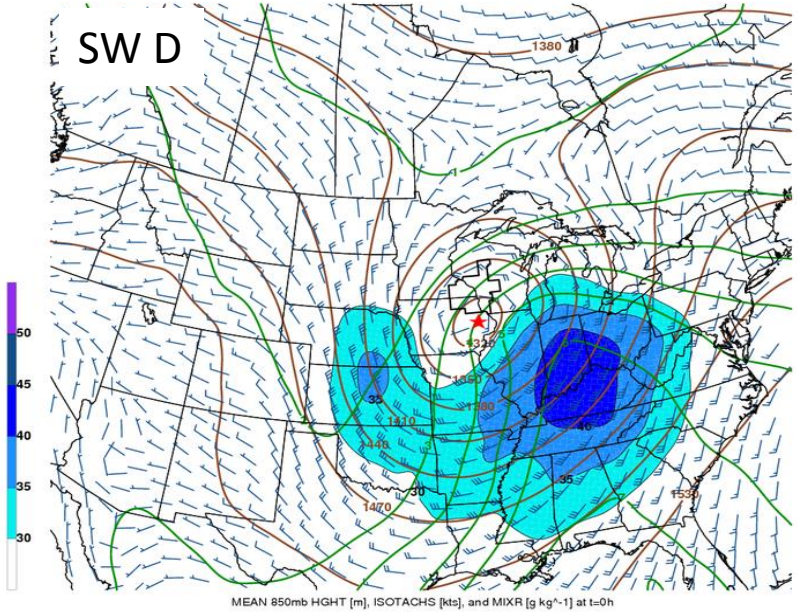
Time: Heavy Snow Ending (12h)

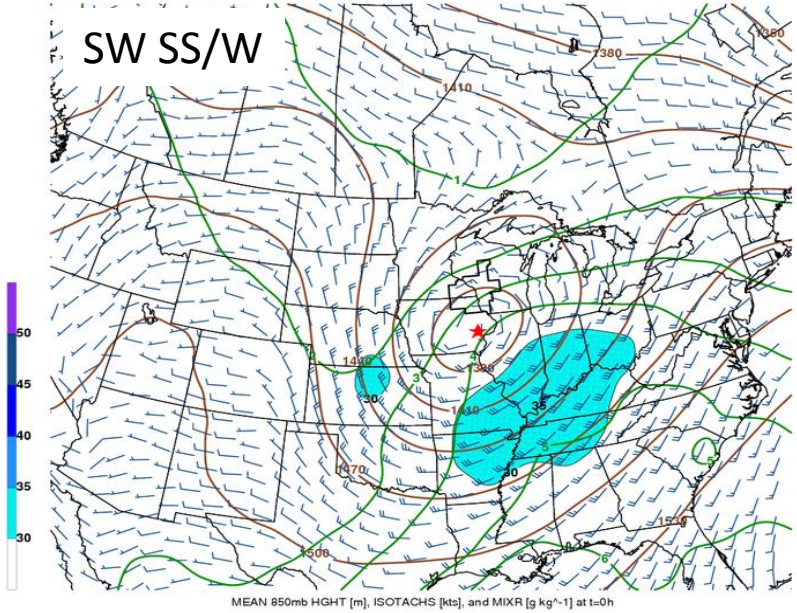
- Wind Max: NW CAA, SW WAA
- Mixing Ratio NW 2-3g/kg, SW 3-4g/kg
- Low Center: NW steady state vs. SW D

~30m falls every 6 hours



850mb Heights, Winds, **Isotachs (kts)**, Mixing Ratio

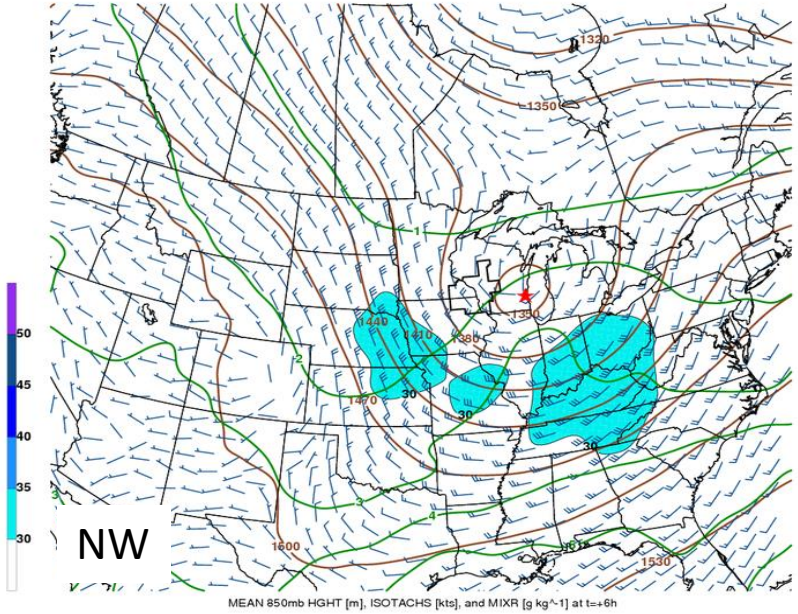




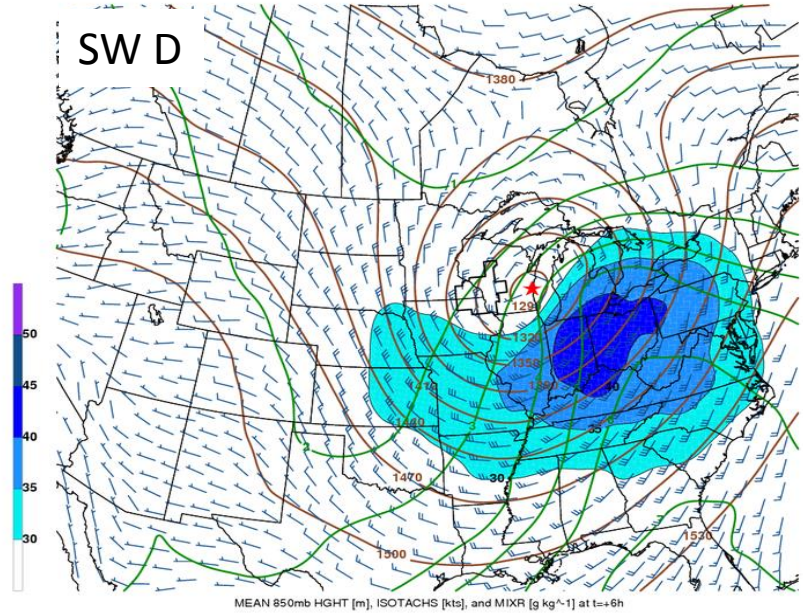
Time:
T+6hrs
Heavy
Snow
End

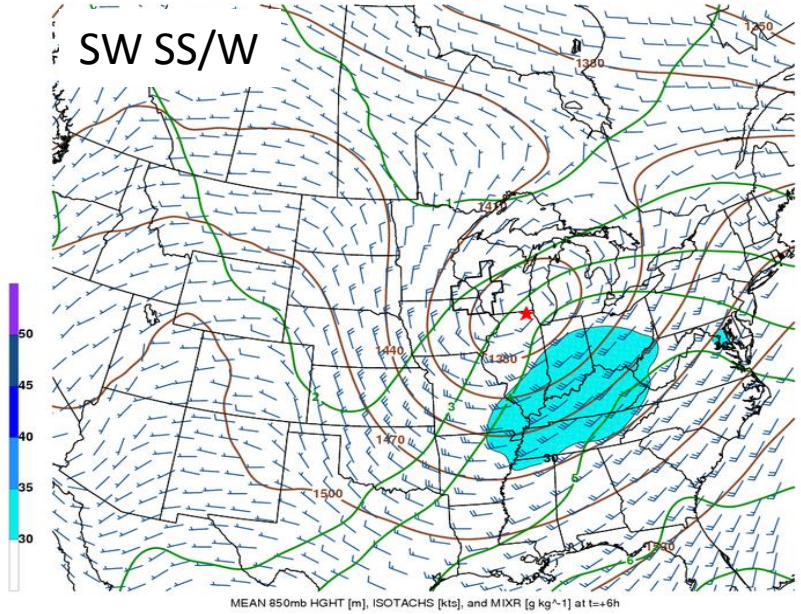
- Wind Max: NW CAA, SW WAA
- Mixing Ratio NW 2-3g/kg, SW 3-4g/kg
- Low Center: NW steady state vs. SW D

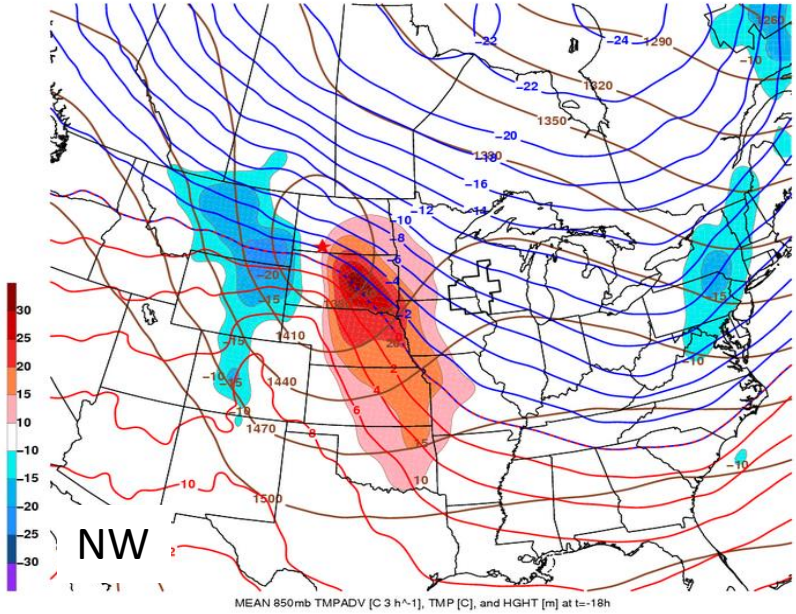
~30m falls every 6 hours



850mb Heights, Winds, **Isotachs (kts)**, Mixing Ratio



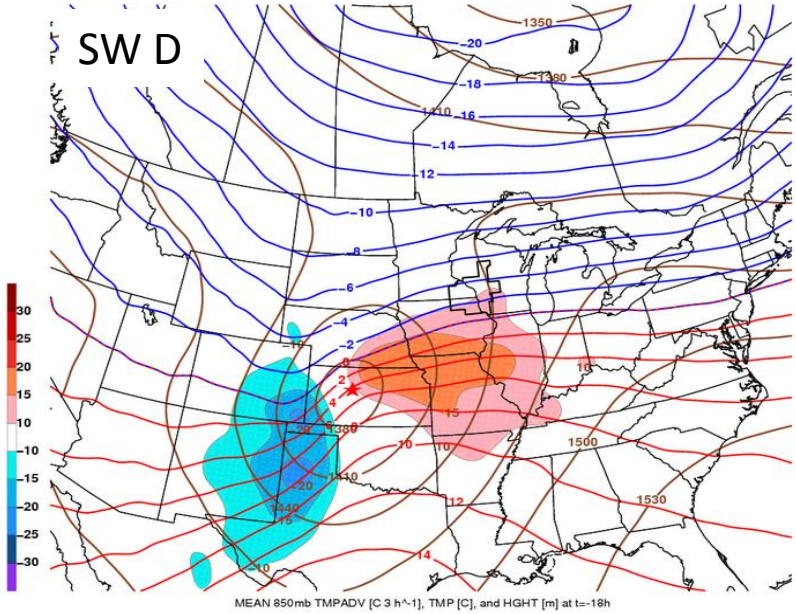


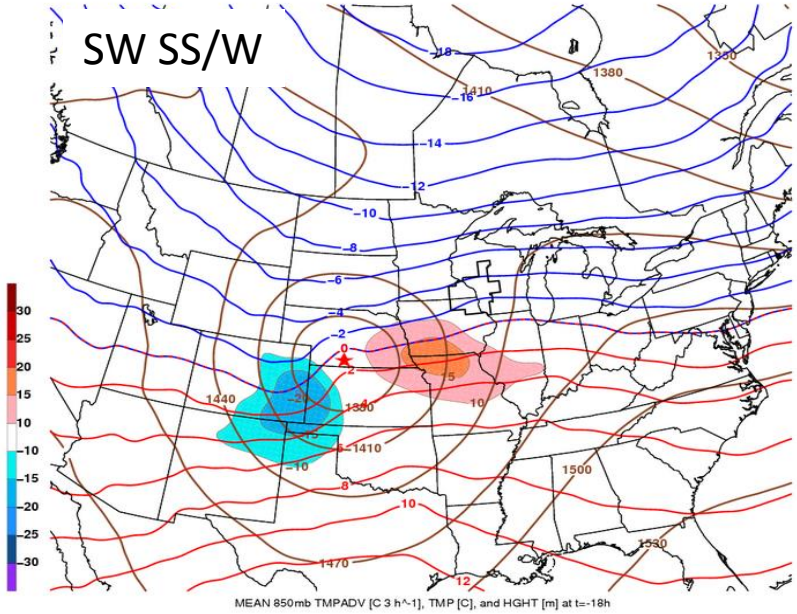


Time: t-6hrs Heavy Snow Begin

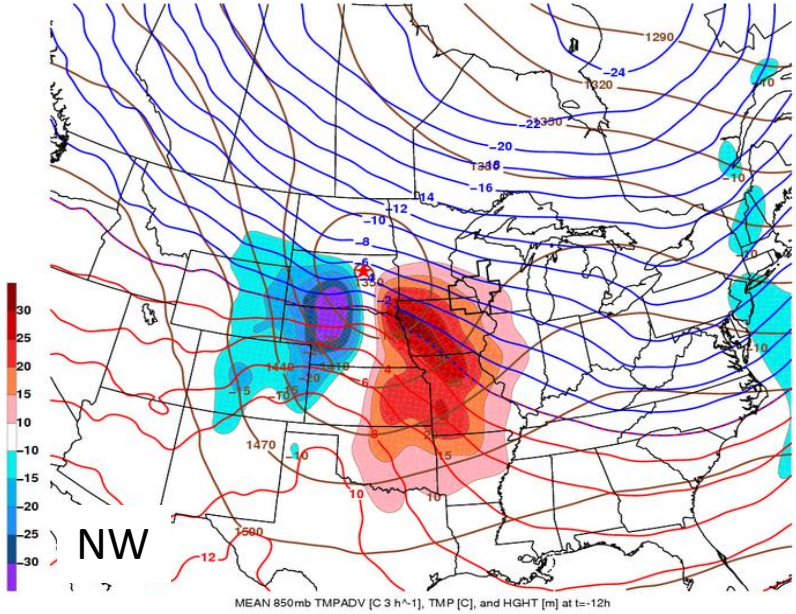
- Similar patterns. NW: Focused WAA.
- SW more S-shaped baroclinic zone.
- Heavy snow: NW -7 to -11C, SW SS/W -4 to -8C, SW -2 to -6C
- WAA strong but temperature steady. Implied vertical motion.

850mb Height, **Temperature Advection**, Isotherms





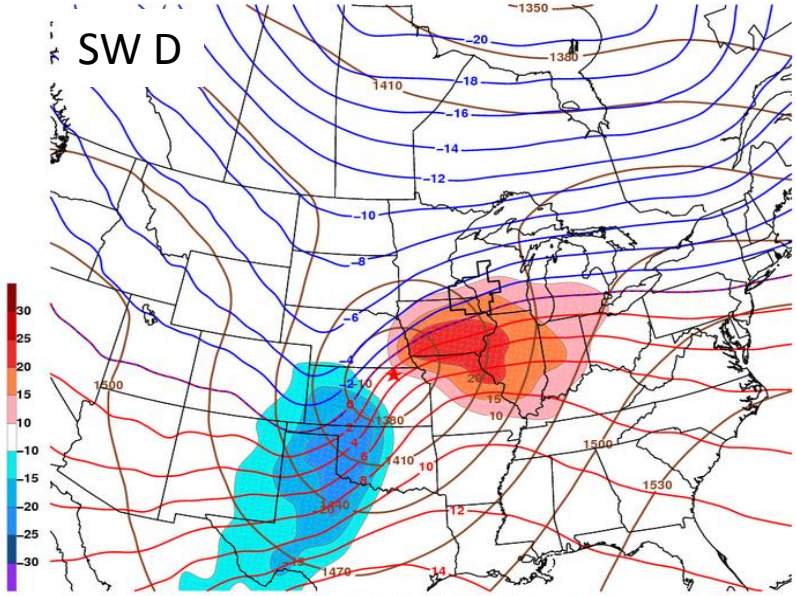
850mb Low indicated by "★"

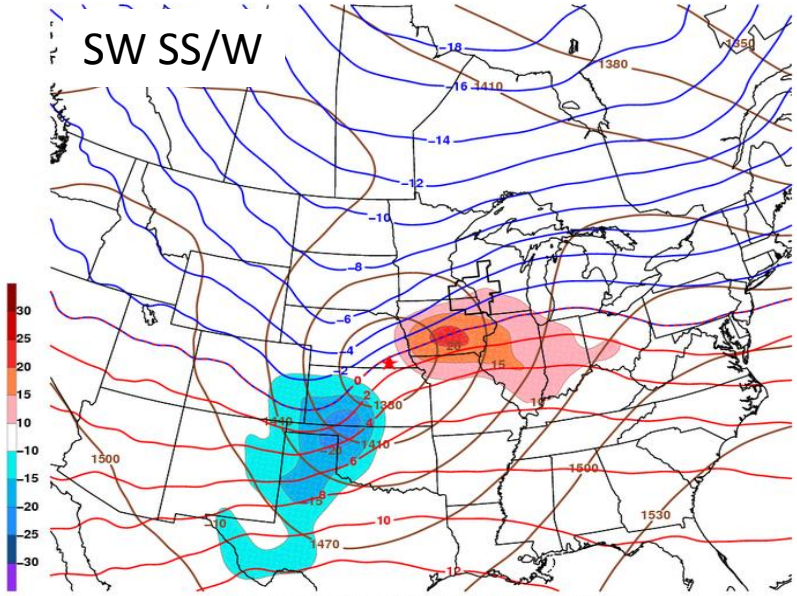


Time: Heavy Snow Begin (00h)

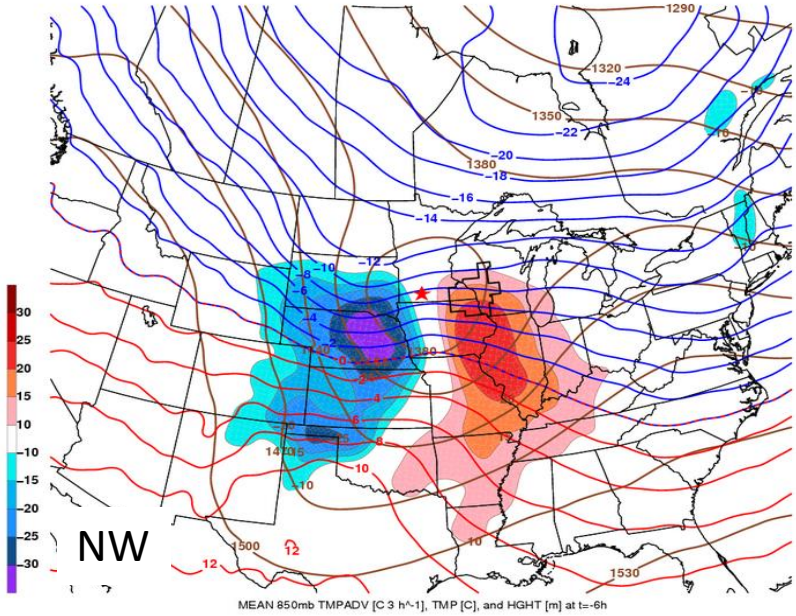
- Similar patterns. NW: Focused WAA.
- SW more S-shaped baroclinic zone.
- Heavy snow: NW -7 to -11C, SW SS/W -4 to -8C, SW -2 to -6C
- WAA strong but temperature steady. Implied vertical motion.

850mb Height, **Temperature Advection**, Isotherms





850mb Low indicated by "★"

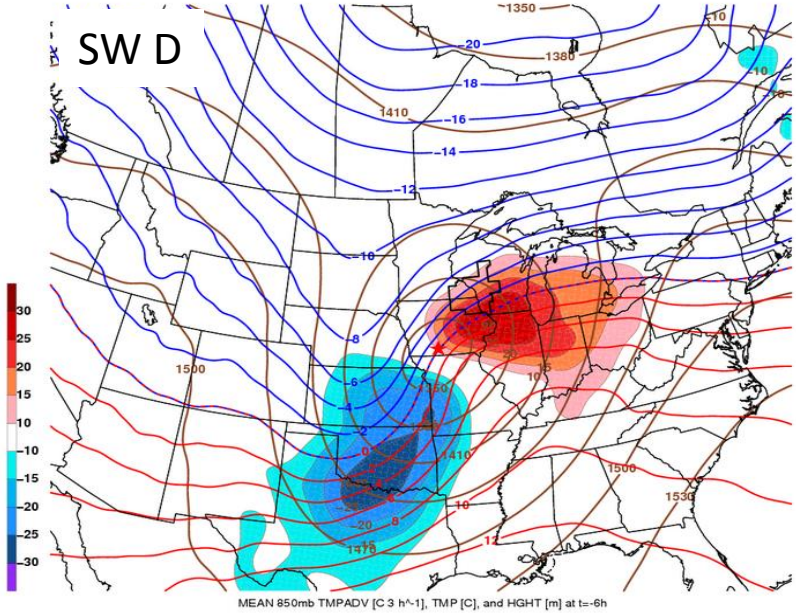


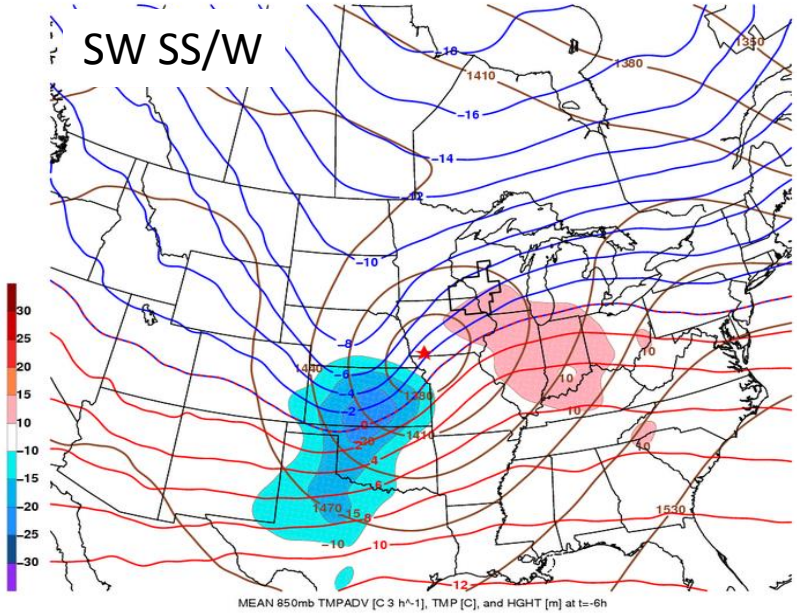
Time: Heavy Snow

(06h)

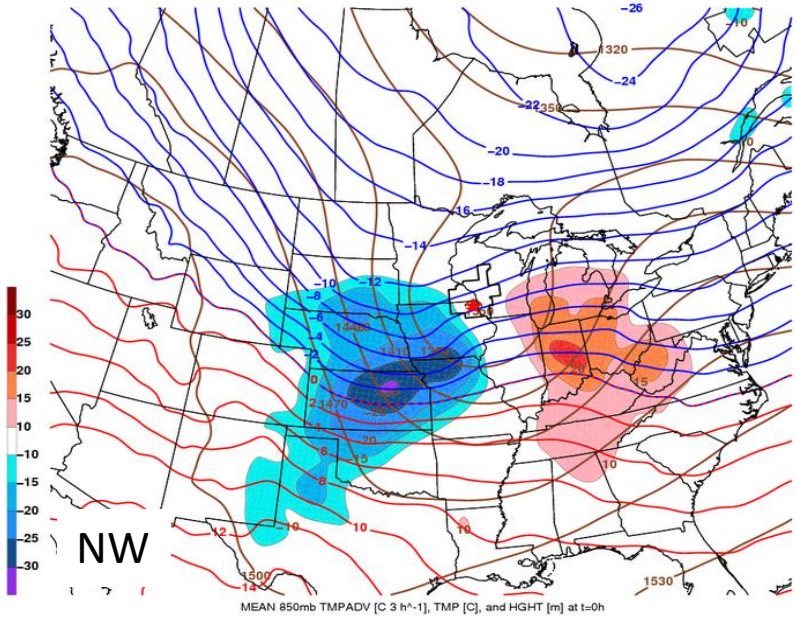
- Similar patterns. NW: Focused WAA.
- SW more S-shaped baroclinic zone.
- Heavy snow: NW -7 to -11C, SW SS/W -4 to -8C, SW -2 to -6C
- WAA strong but temperature steady. Implied vertical motion.

850mb Height, **Temperature Advection**, Isotherms





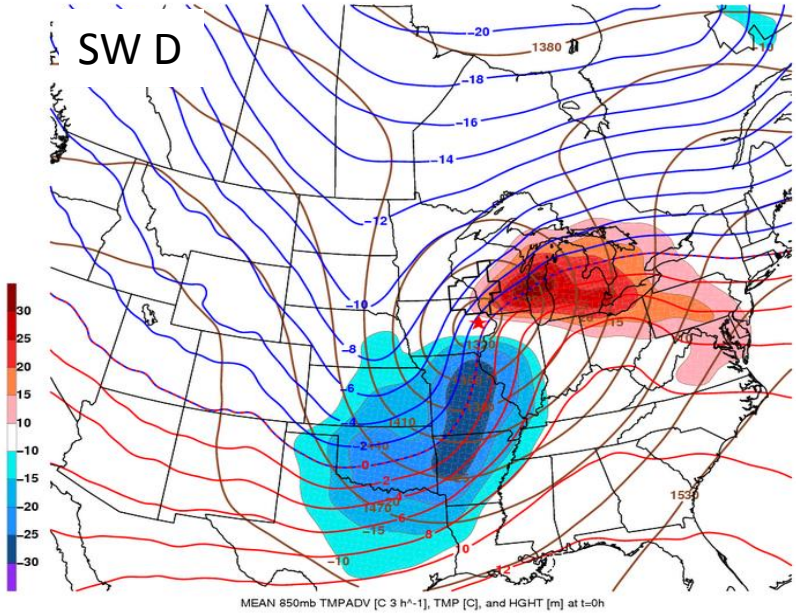
850mb Low indicated by "★"

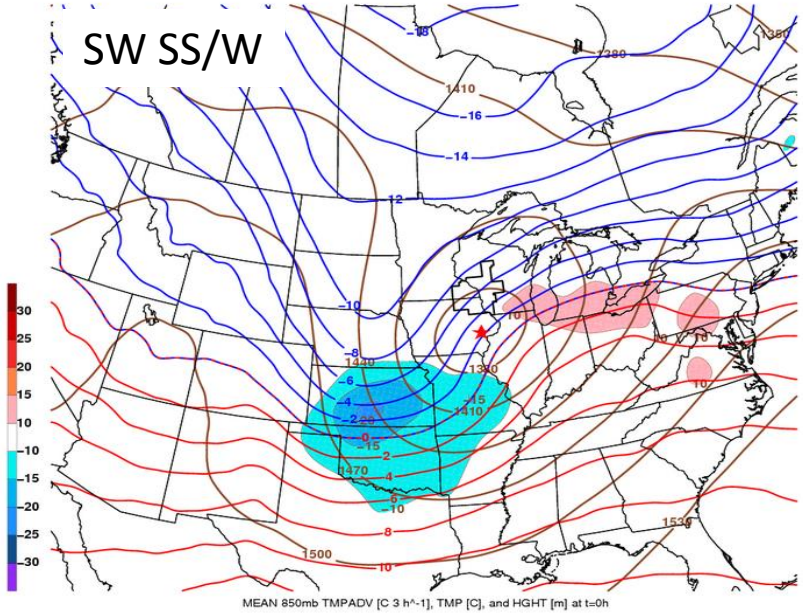


Time: Heavy Snow Ending (12h)

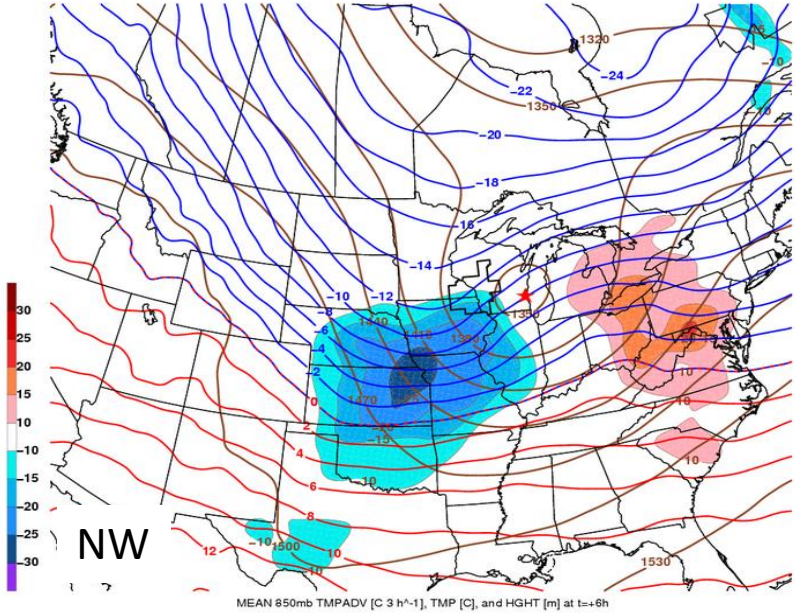
- Similar patterns. NW: Focused WAA.
- SW more S-shaped baroclinic zone.
- Heavy snow: NW -7 to -11C, SW SS/W -4 to -8C, SW -2 to -6C
- WAA strong but temperature steady. Implied vertical motion.

850mb Height, **Temperature Advection**, Isotherms





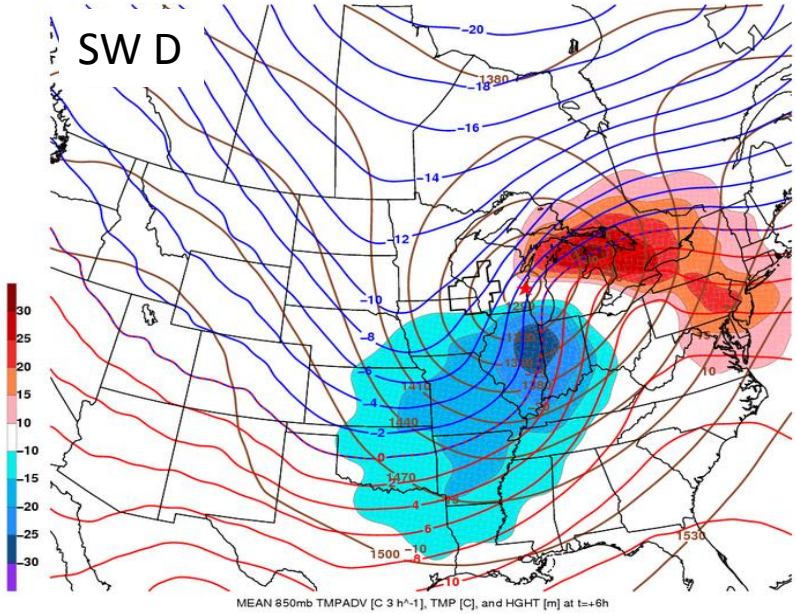
850mb Low indicated by "★"

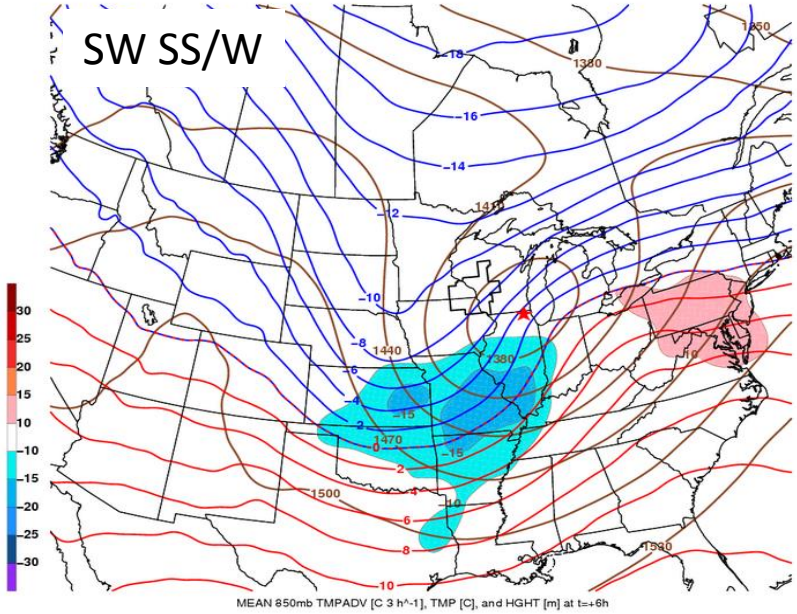


Time:
T+6hrs
Heavy
Snow
End

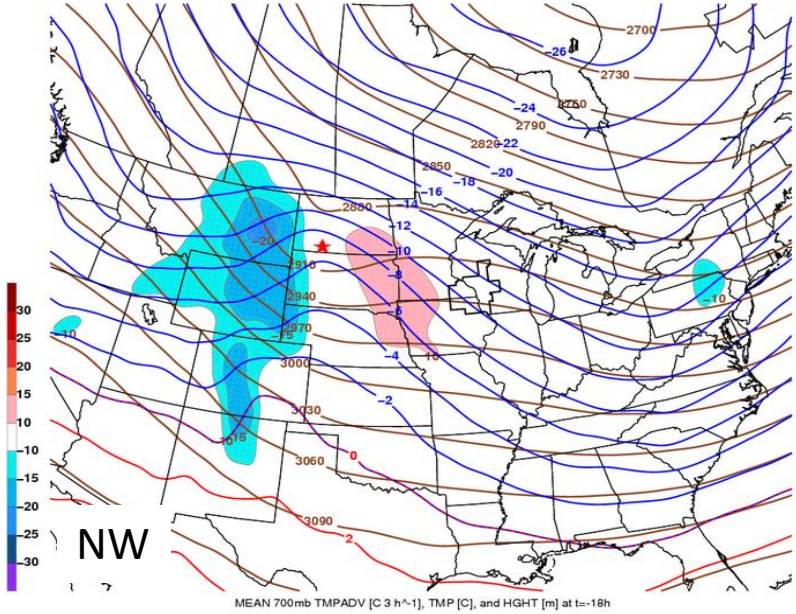
- Similar patterns. NW: Focused WAA.
- SW more S-shaped baroclinic zone.
- Heavy snow: NW -7 to -11C, SW SS/W -4 to -8C, SW -2 to -6C
- WAA strong but temperature steady. Implied vertical motion.

850mb Height, **Temperature Advection**, Isotherms





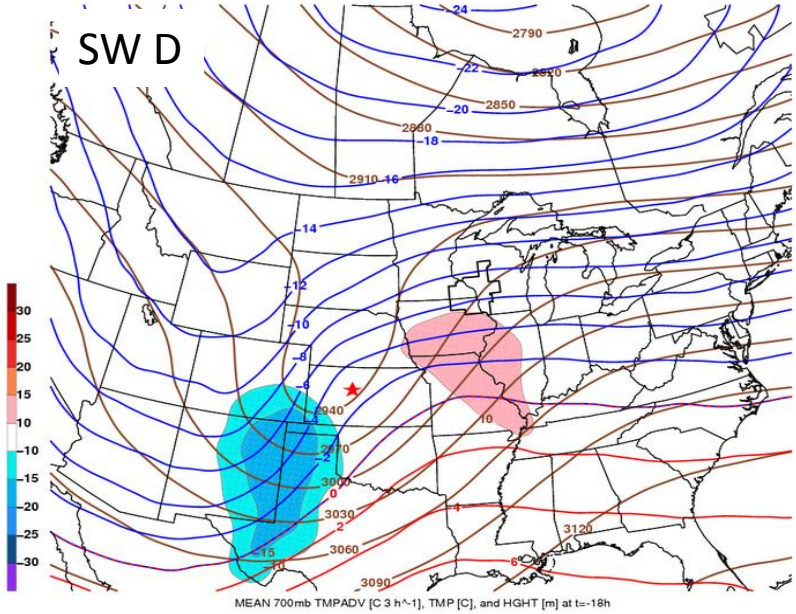
850mb Low indicated by "★"

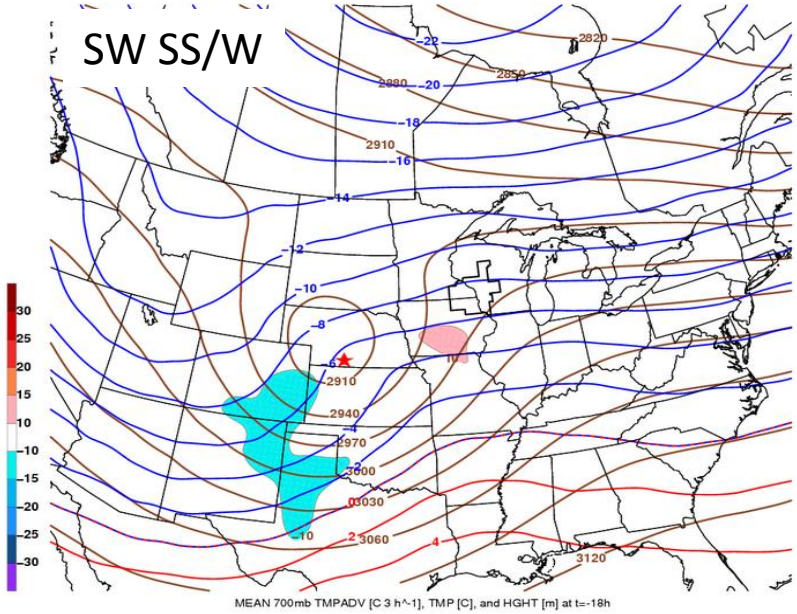


Time: t-6hrs Heavy Snow Begin

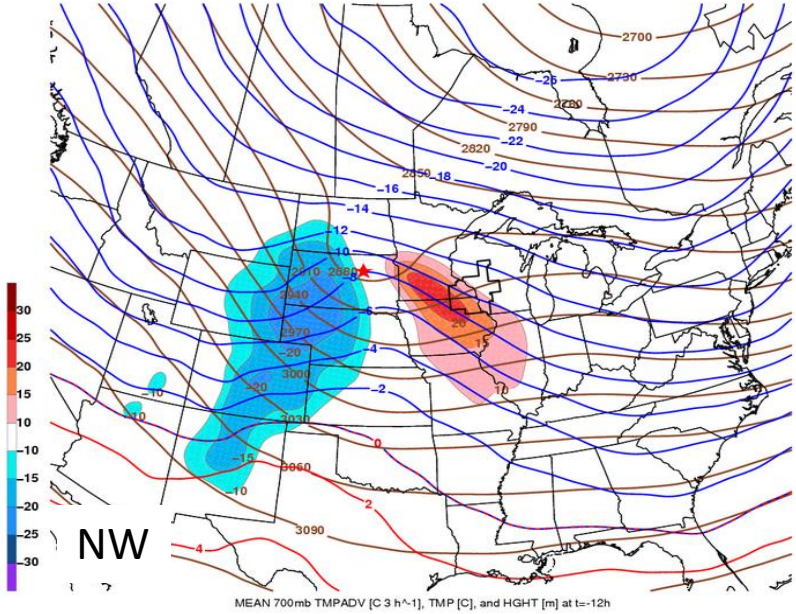
- NW: Very strong upstream WAA.
- Heavy snow: NW -10C, SW SS/W -8C vs. SW -6C
- SW SS/W – Almost no signal.
- Dendrite regime important?

700mb Height, **Temperature Advection**, Isotherms





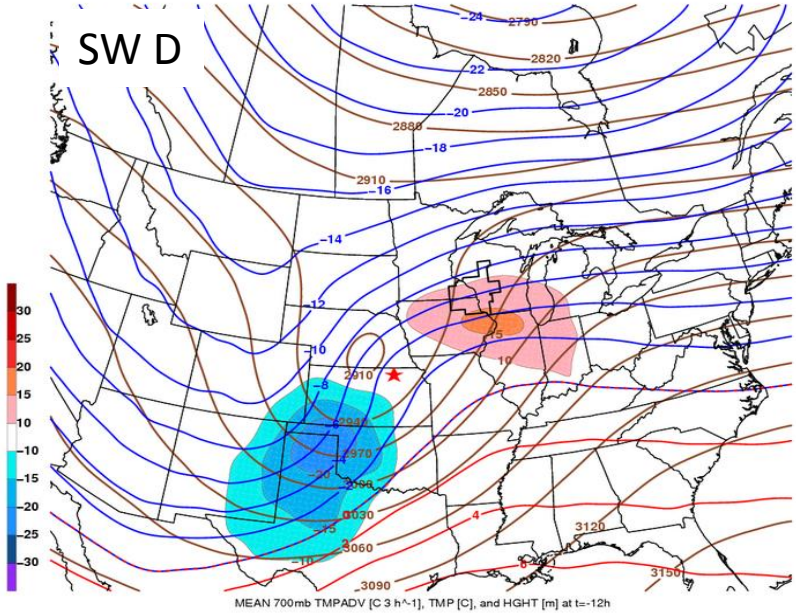
850mb Low indicated by "★"

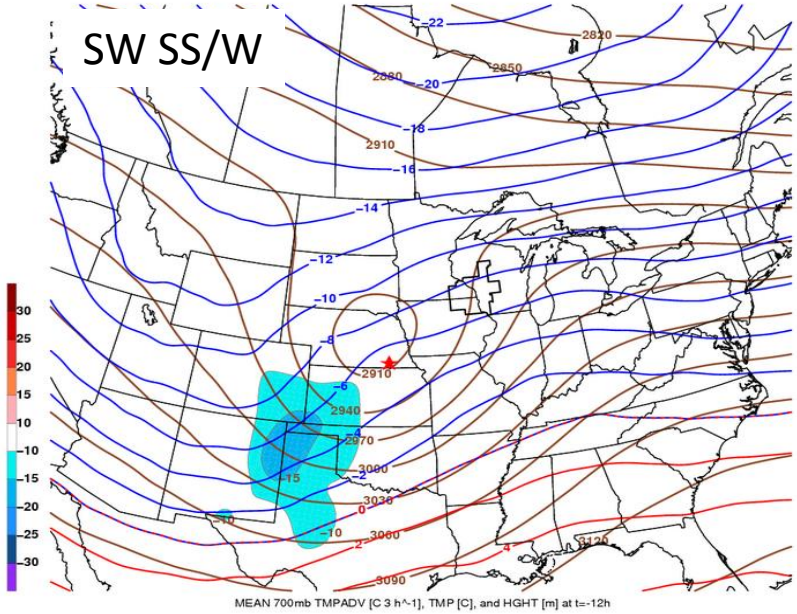


Time: Heavy Snow Begin (00h)

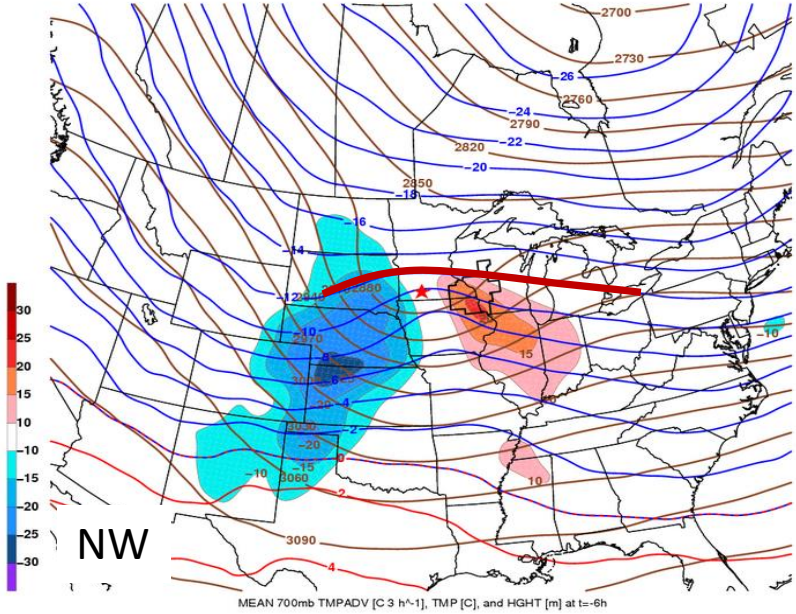
- NW: Very strong upstream WAA.
- Heavy snow: NW -10C, SW SS/W -8C vs. SW -6C
- SW SS/W – Almost no signal.
- Dendrite regime important?

700mb Height, **Temperature Advection**, Isotherms





850mb Low indicated by "★"

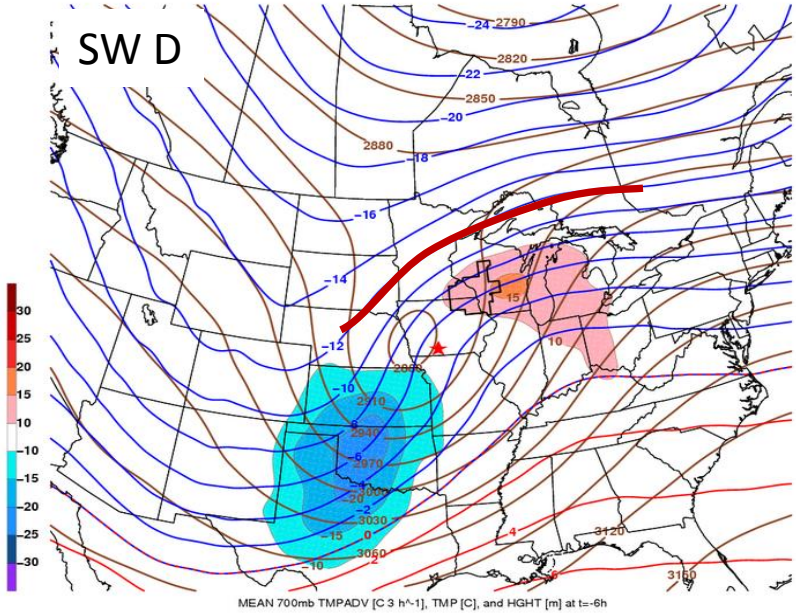


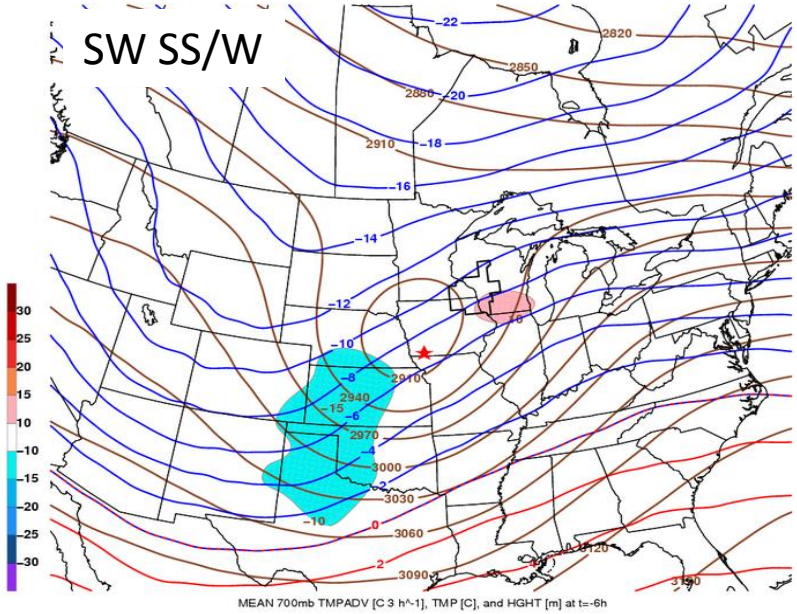
Time: Heavy Snow

(06h)

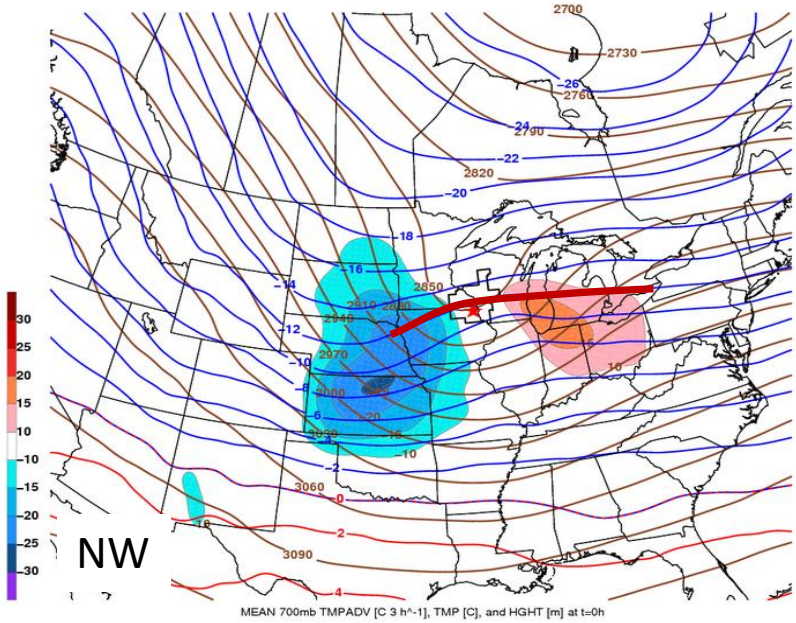
- NW: Very strong upstream WAA.
- Heavy snow: NW -10C, SW SS/W -8C vs. SW -6C
- SW SS/W – Almost no signal.
- Dendrite regime important?

700mb Height, **Temperature Advection**, Isotherms





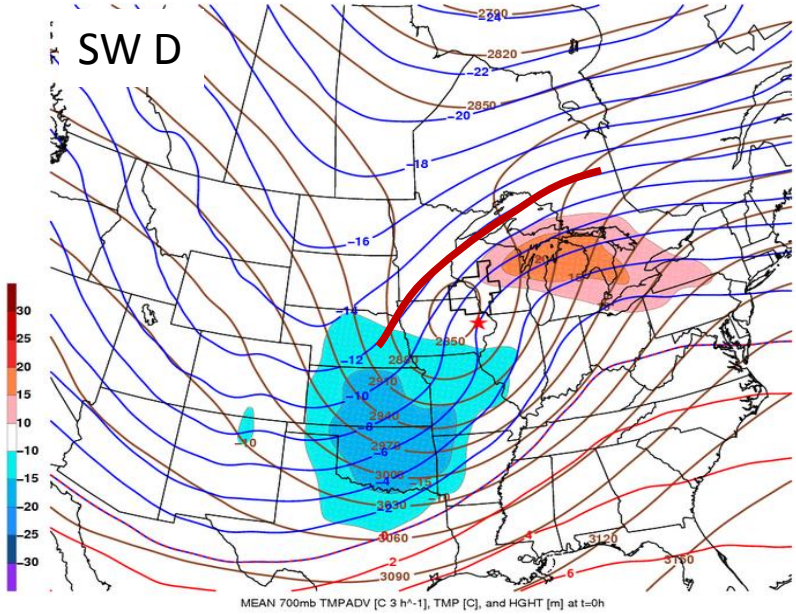
850mb Low indicated by "★"

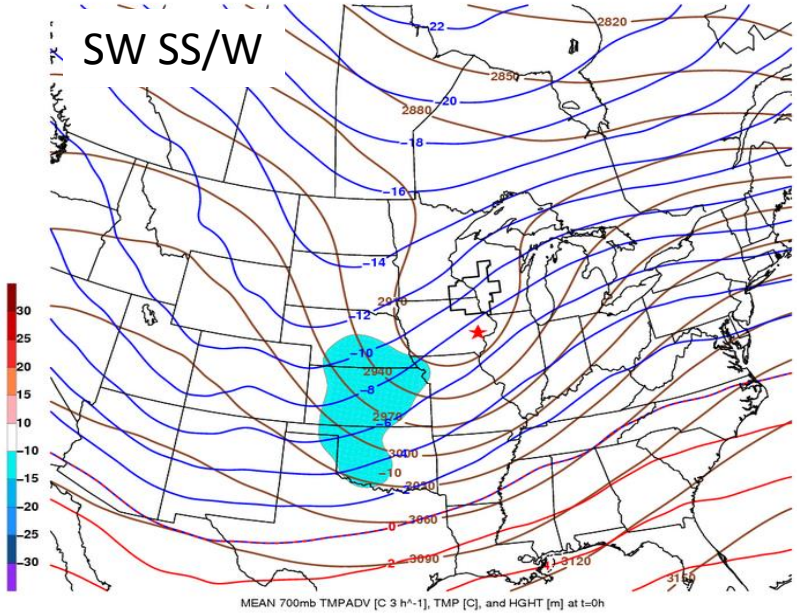


Time: Heavy Snow Ending (12h)

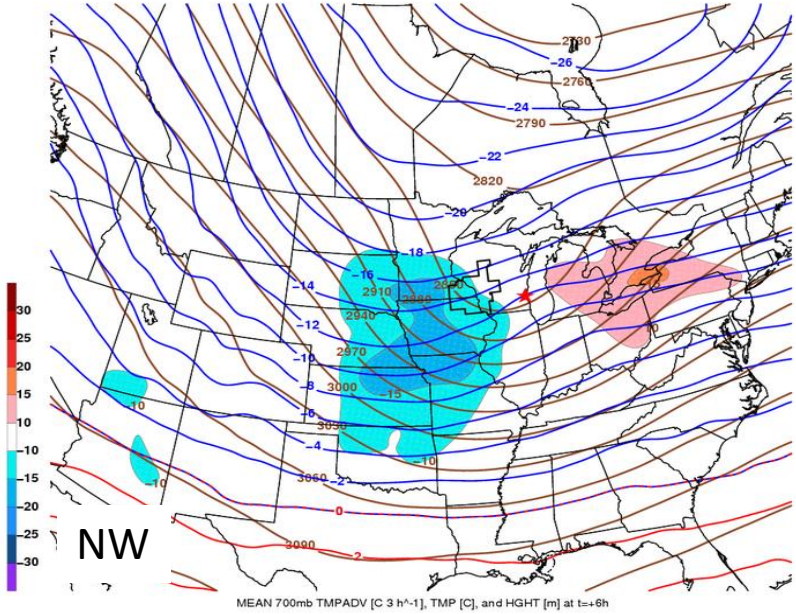
- NW: Very strong upstream WAA.
- Heavy snow: NW -10C, SW SS/W -8C vs. SW -6C
- SW SS/W – Almost no signal.
- Dendrite regime important?

700mb Height, **Temperature Advection**, Isotherms





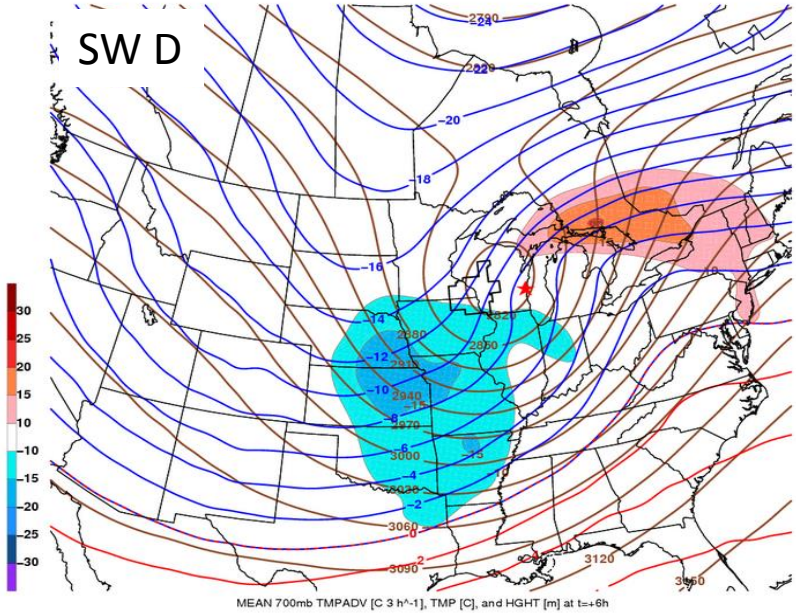
850mb Low indicated by "★"

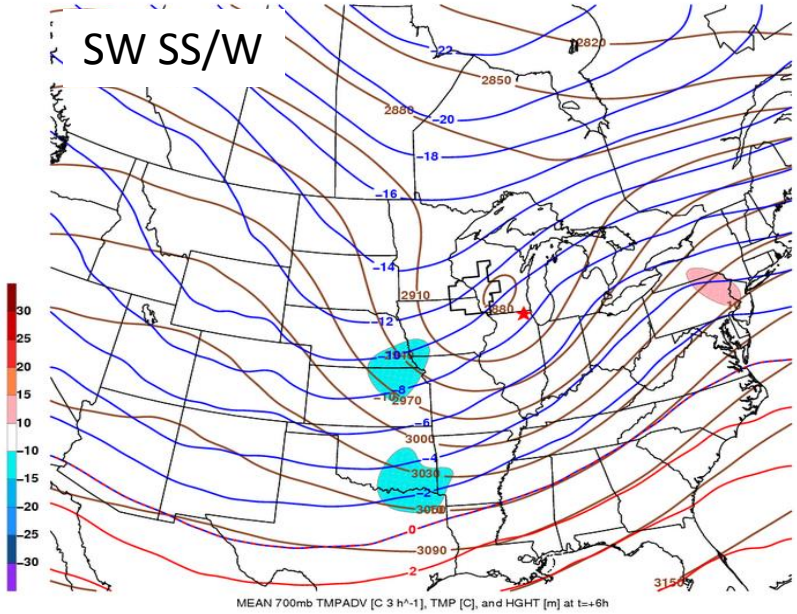


Time:
T+6hrs
Heavy
Snow
End

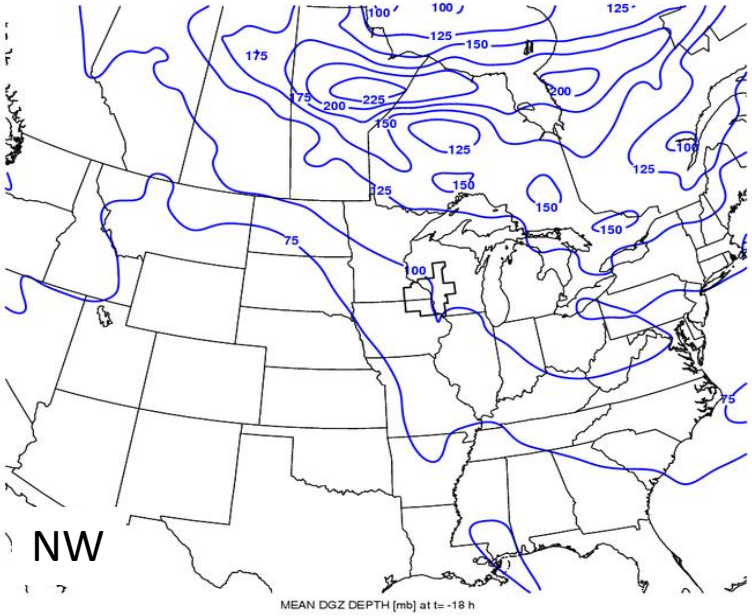
- NW: Very strong upstream WAA.
- Heavy snow: NW -10C, SW SS/W -8C vs. SW -6C
- SW SS/W – Almost no signal.
- Dendrite regime important?

700mb Height, **Temperature Advection**, Isotherms





850mb Low indicated by "★"

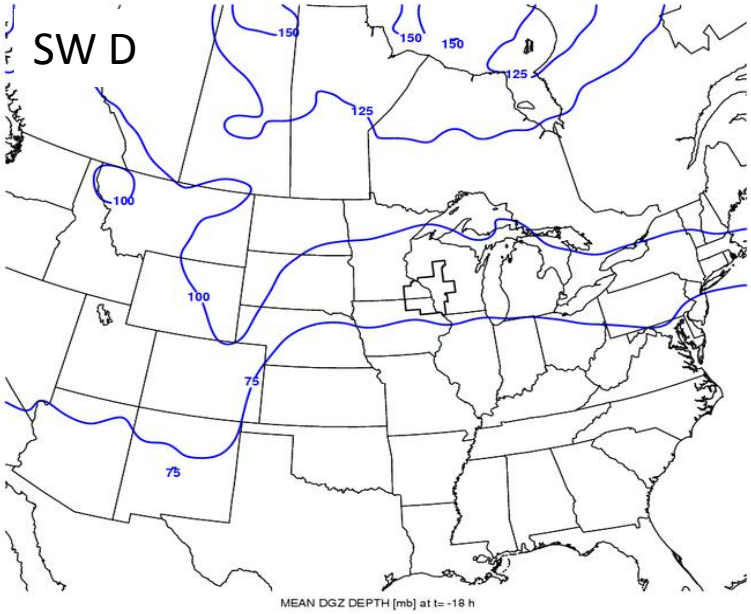


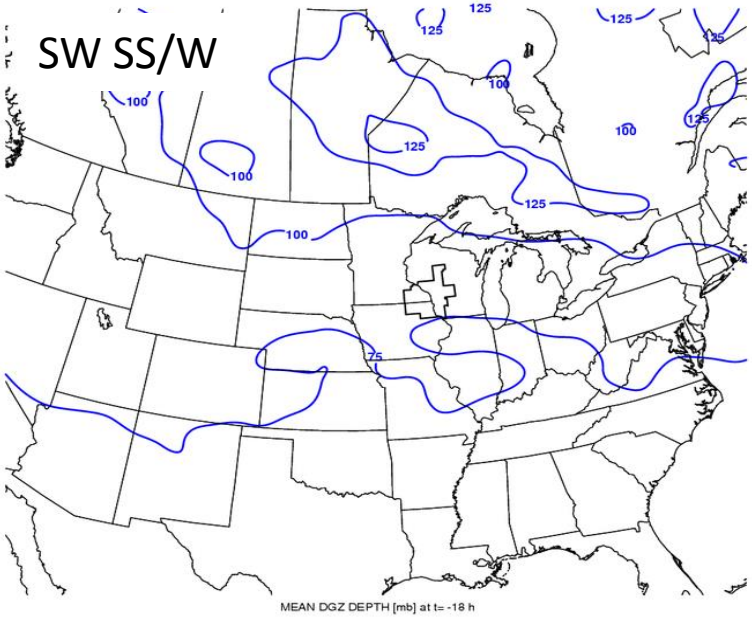
Time: t-6hrs Heavy Snow Begin

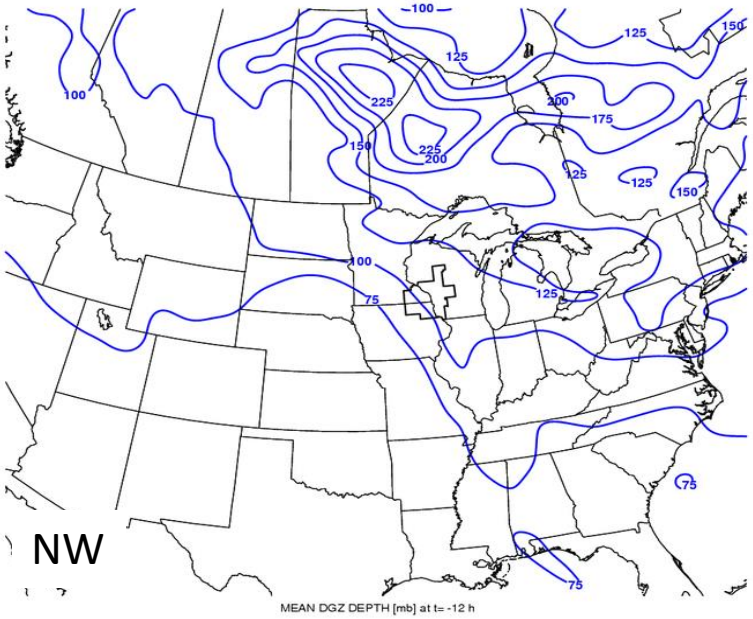
- NW: Depth nears 125 mb by end of snow period.

- Bottom line: Dendritic crystal type not a large contribution to most heavy snow events. Certainly not SW cases.

Dendrite Growth Region Depth (-12C to -18C, mb)







Time: Heavy Snow Begin (00h)

- NW: Depth nears 125 mb by end of snow period.

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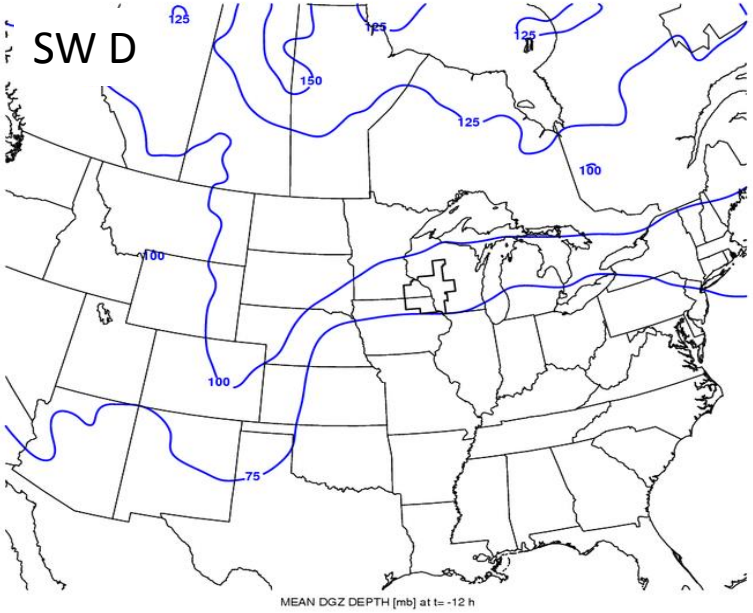
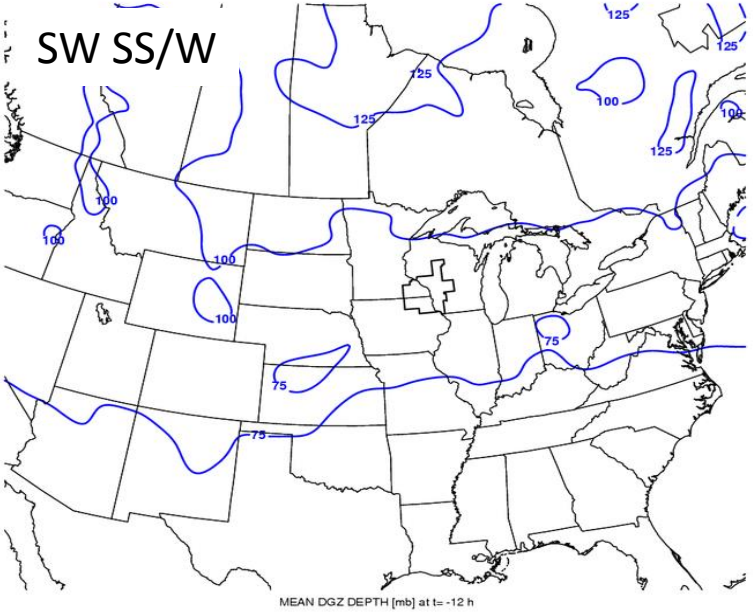
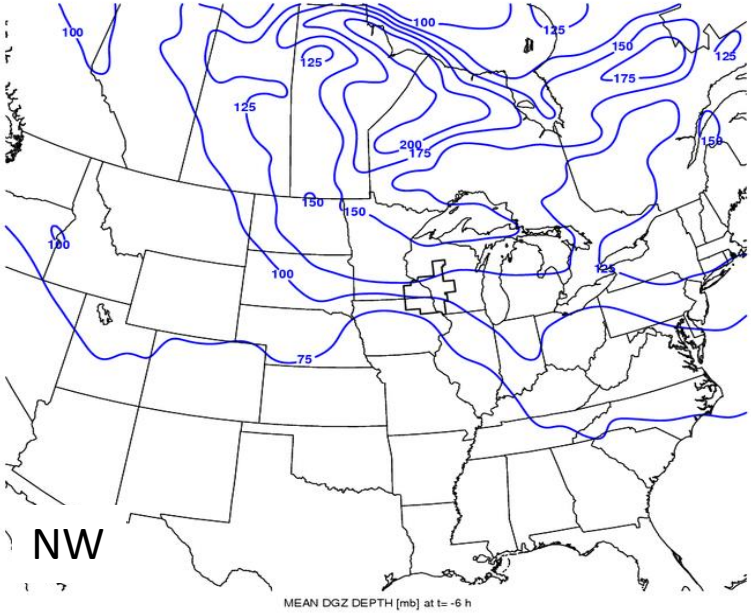
Dendrite Growth Region Depth (-12C to -18C, mb)







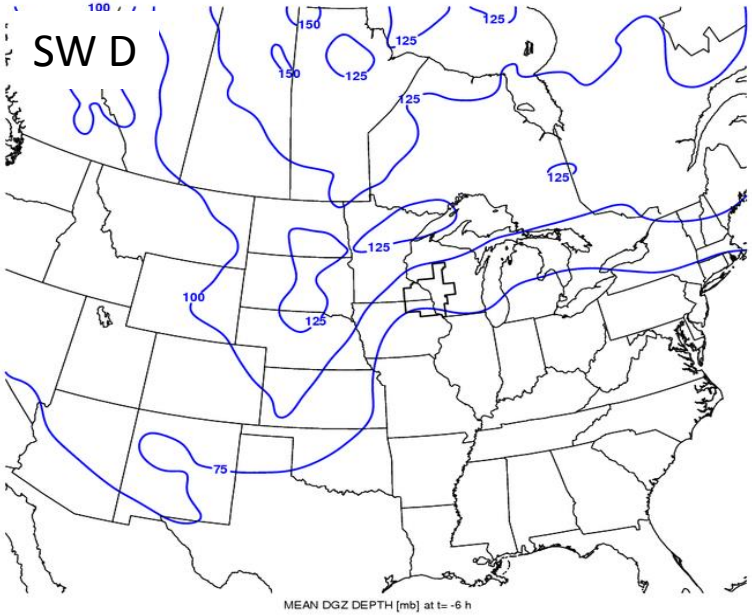
Time: Heavy Snow

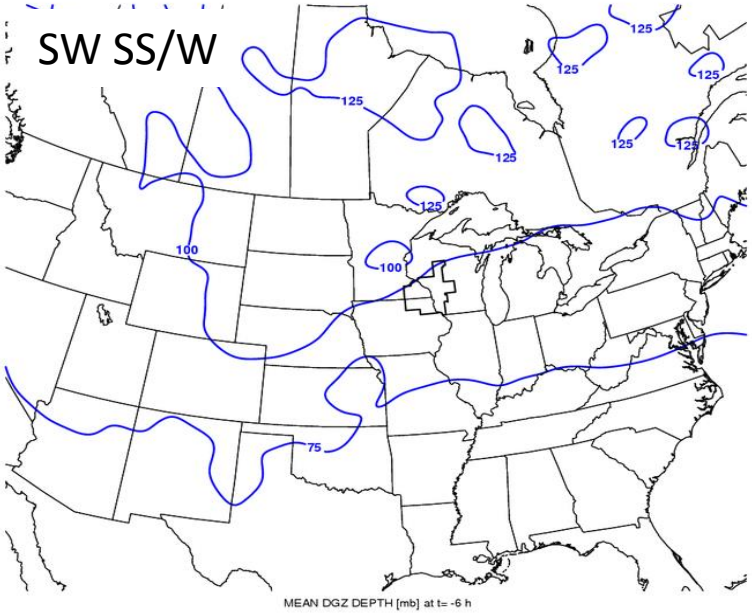
(06h)

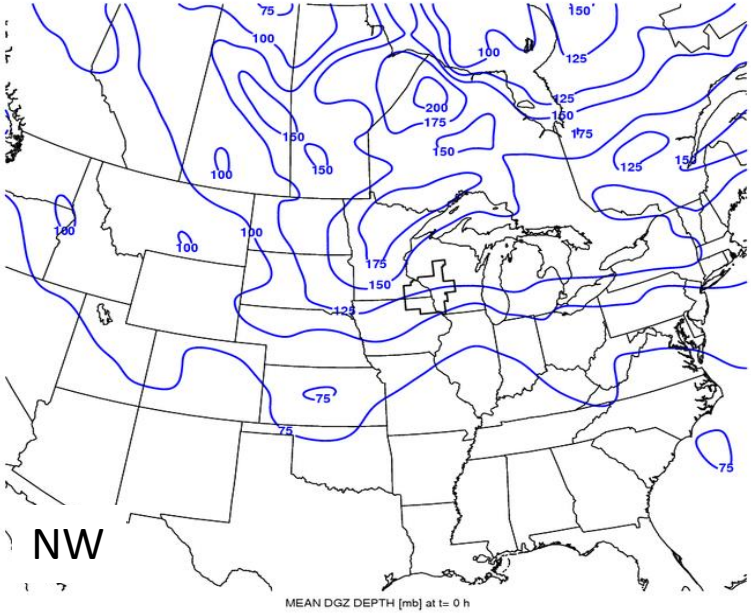
- NW: Depth nears 125 mb by end of snow period.

- Bottom line: Dendritic crystal type not a large contribution to most heavy snow events. Certainly not SW cases.

Dendrite Growth Region Depth (-12C to -18C, mb)





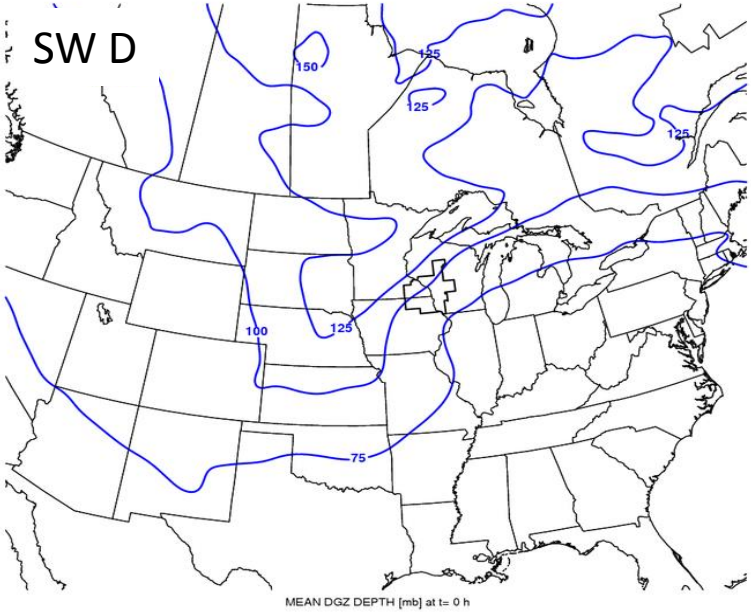


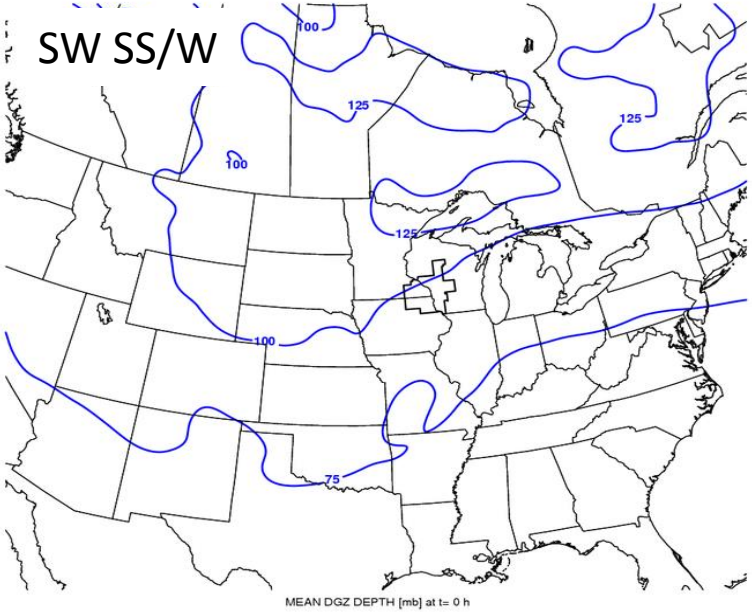
Time: Heavy Snow Ending (12h)

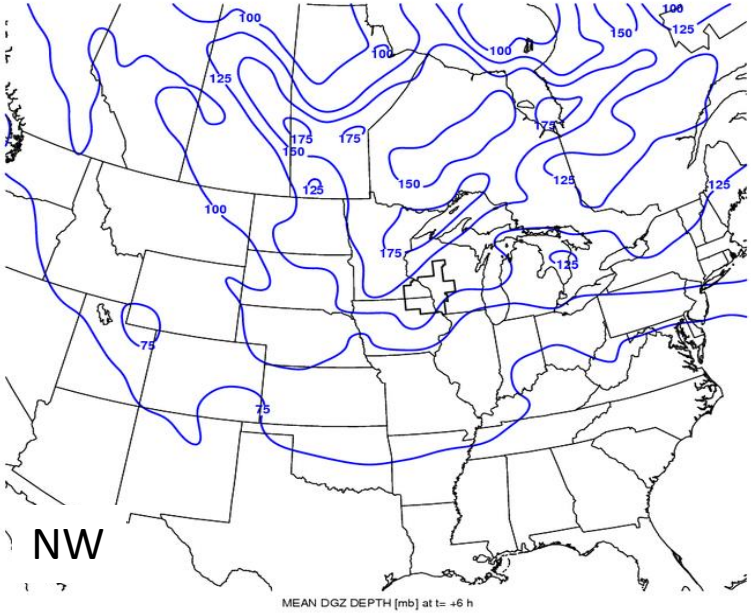
- NW: Depth nears 125 mb by end of snow period.

- Bottom line: Dendritic crystal type not a large contribution to most heavy snow events. Certainly not SW cases.

Dendrite Growth Region Depth (-12C to -18C, mb)







Time: T+6hrs Heavy Snow End

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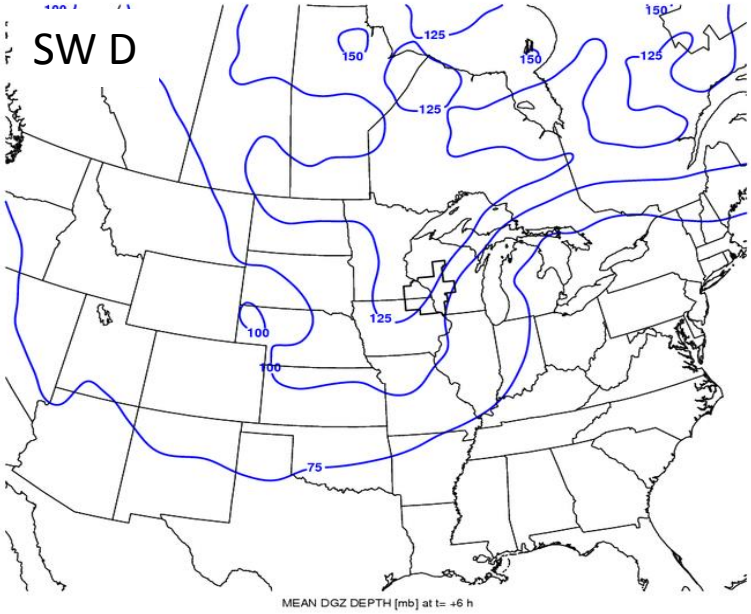
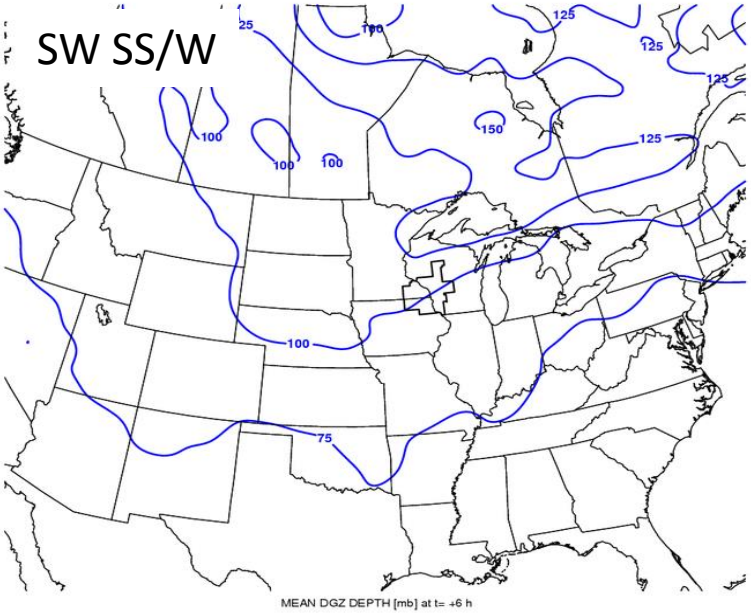
Dendrite Growth Region Depth (-12C to -18C, mb)



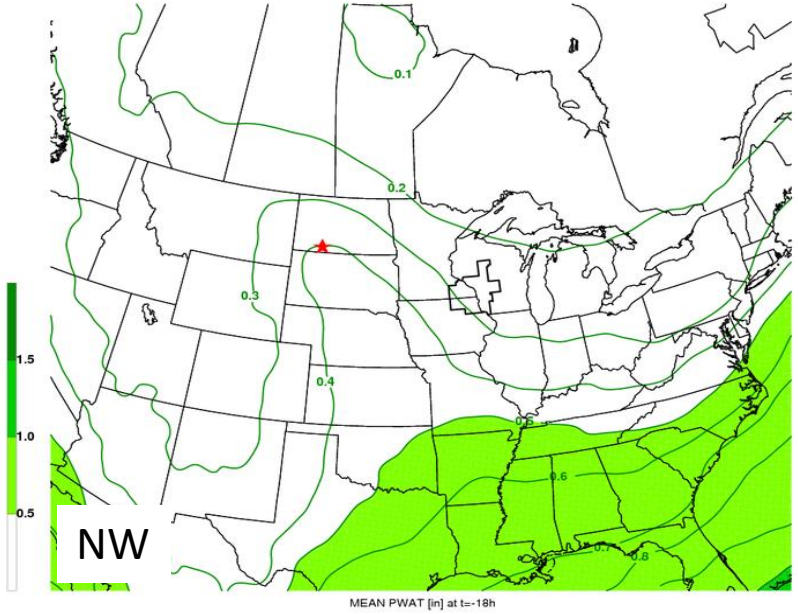


Time: t-6hrs Heavy Snow Begin

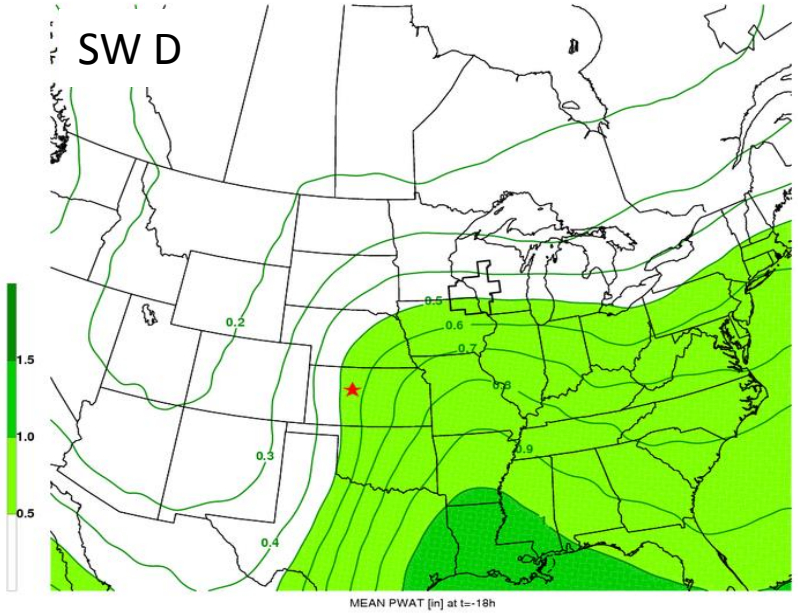
- NW: Up to 133% normal PW (0.30”).
- SW: Up to 200% normal PW.

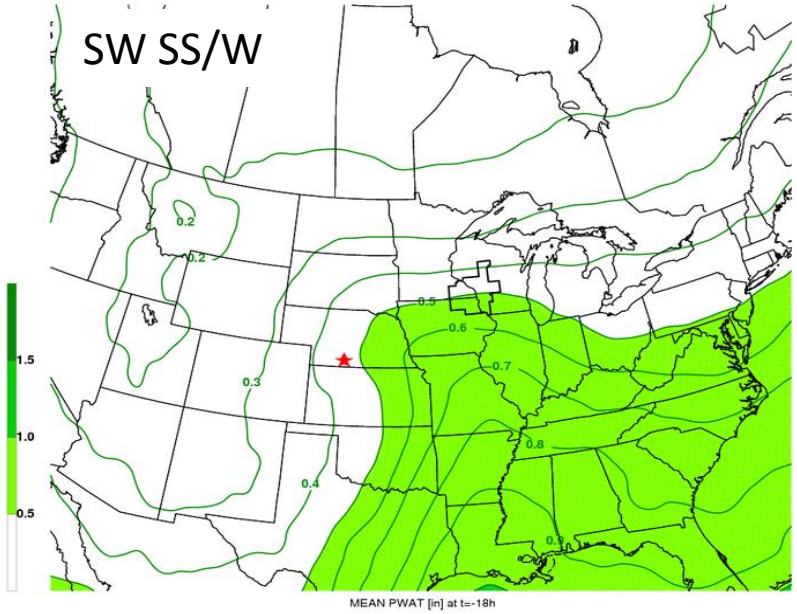
- Moisture axis co-located with strongest forcing on heavy snow area.

- SW D and SS/W similar moisture availability.

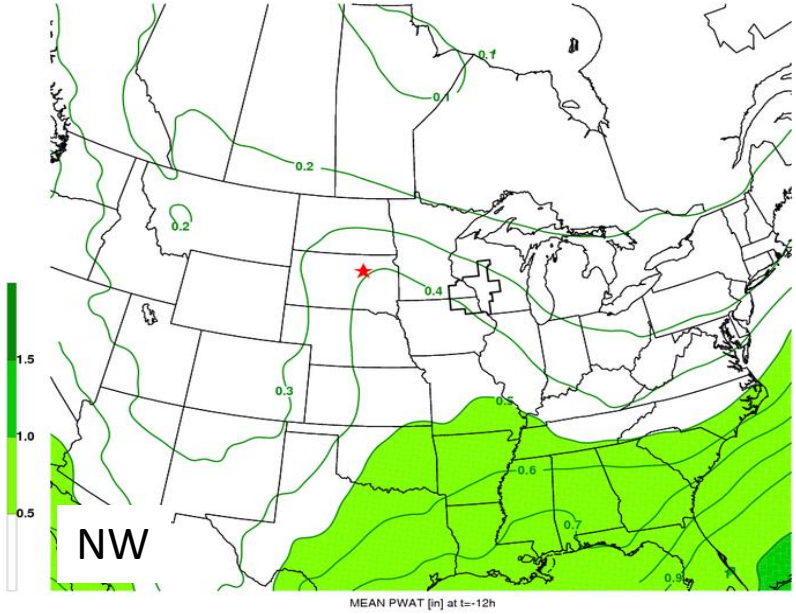


Precipitable Water (in.)





850mb Low indicated by “★“



Time: Heavy Snow Begin (00h)

- NW: Up to 133% normal PW (0.30”).
- SW: Up to 200% normal PW.

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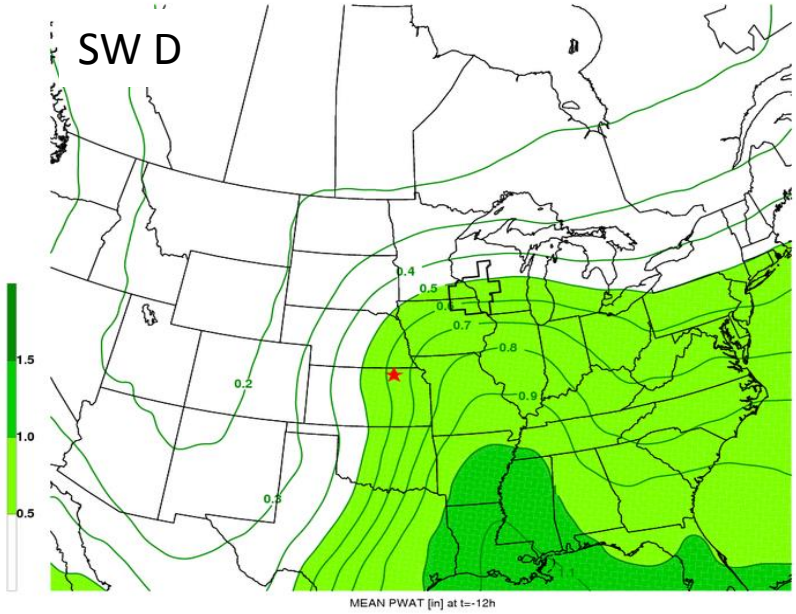
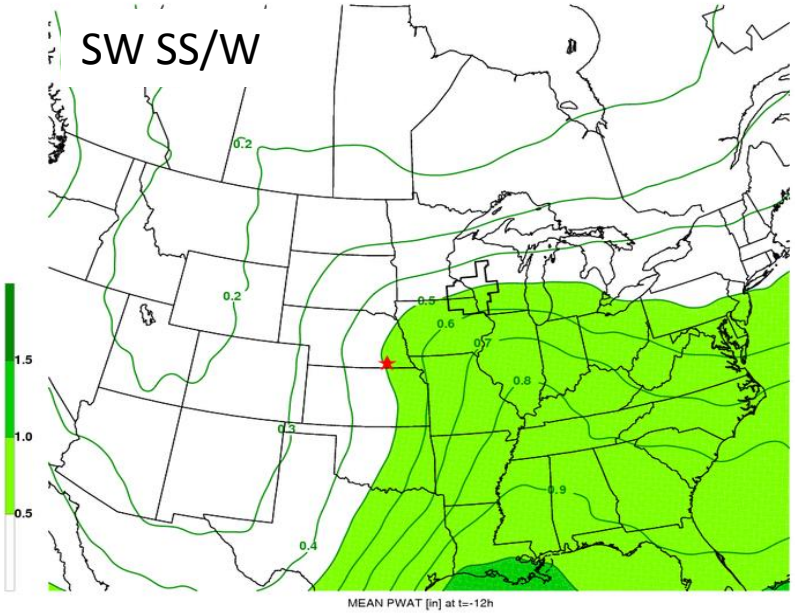
Precipitable Water (in.)





850mb Low indicated by “★“

Time: Heavy Snow

(06h)

- NW: Up to 133% normal PW (0.30”).
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- Moisture axis co-located with strongest forcing on heavy snow area.

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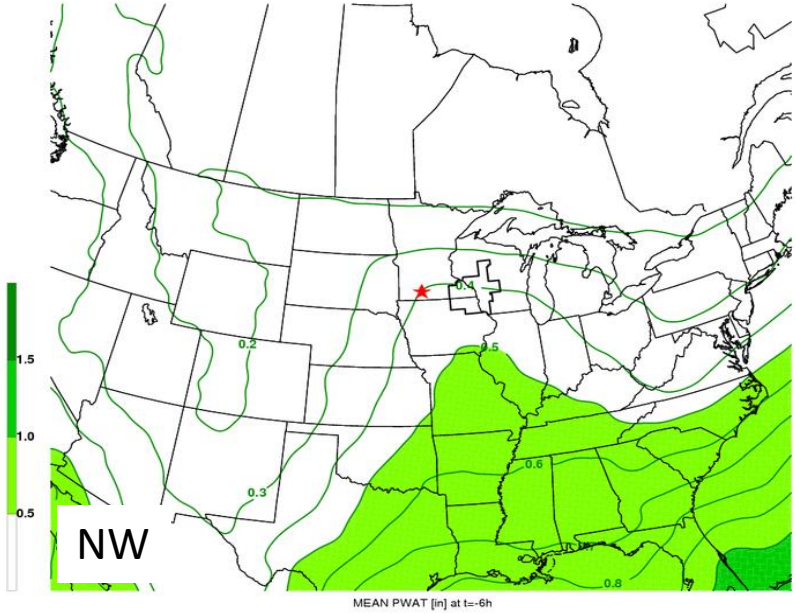
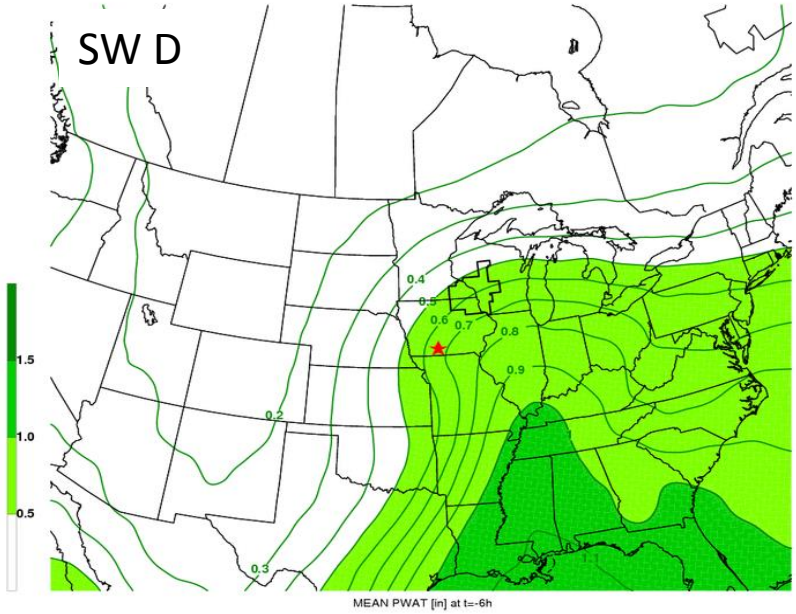
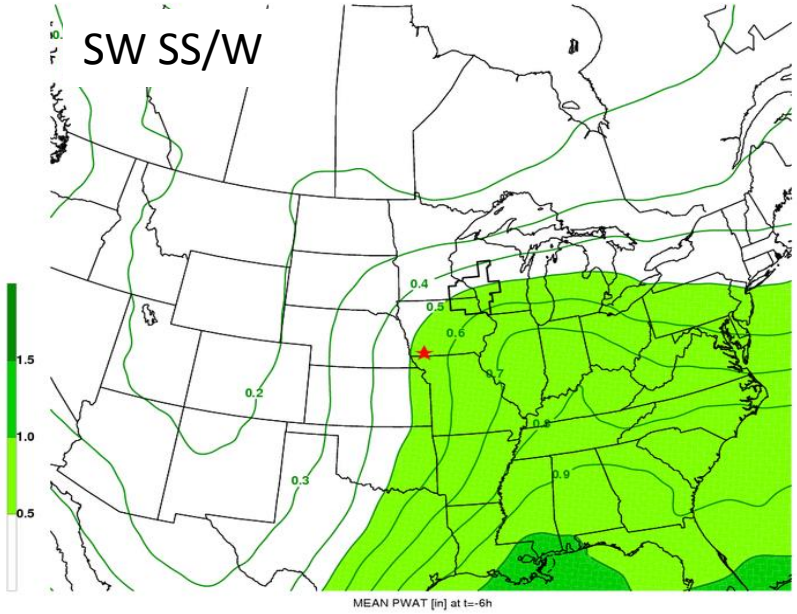


Precipitable Water (in.)





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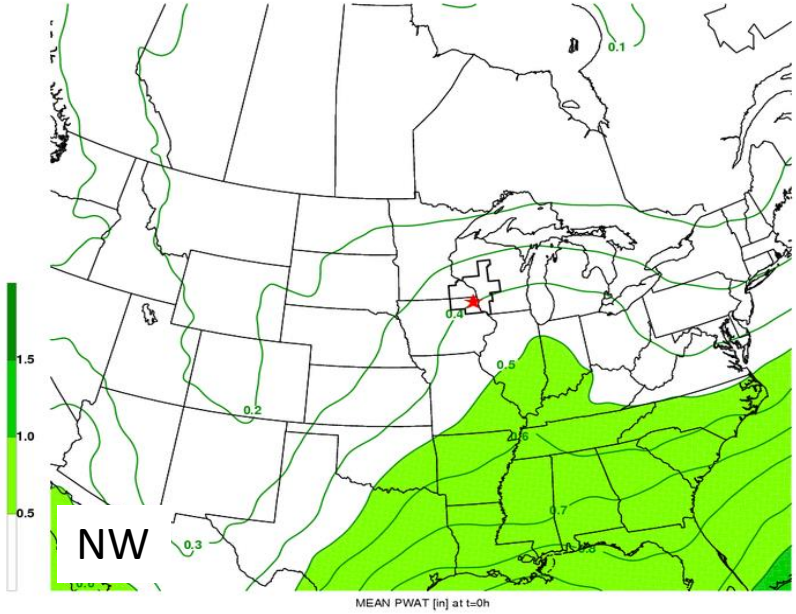


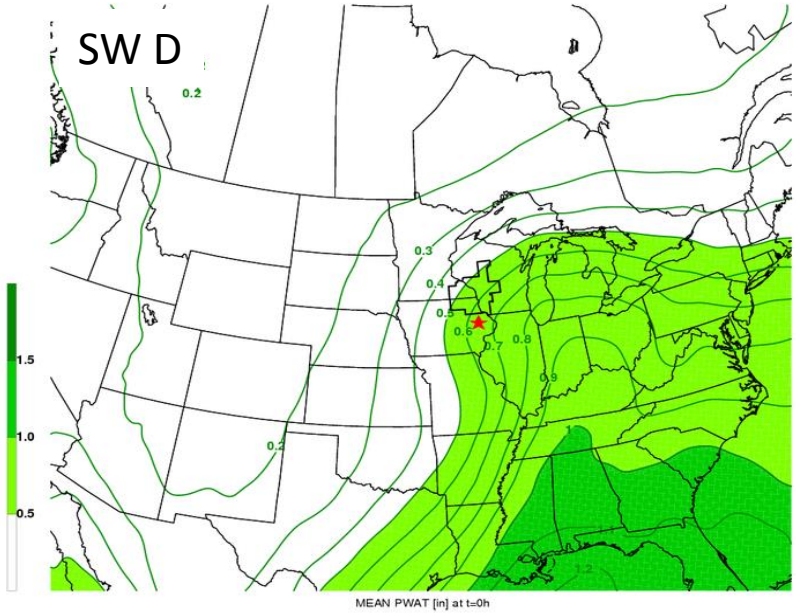
Time: Heavy Snow Ending (12h)

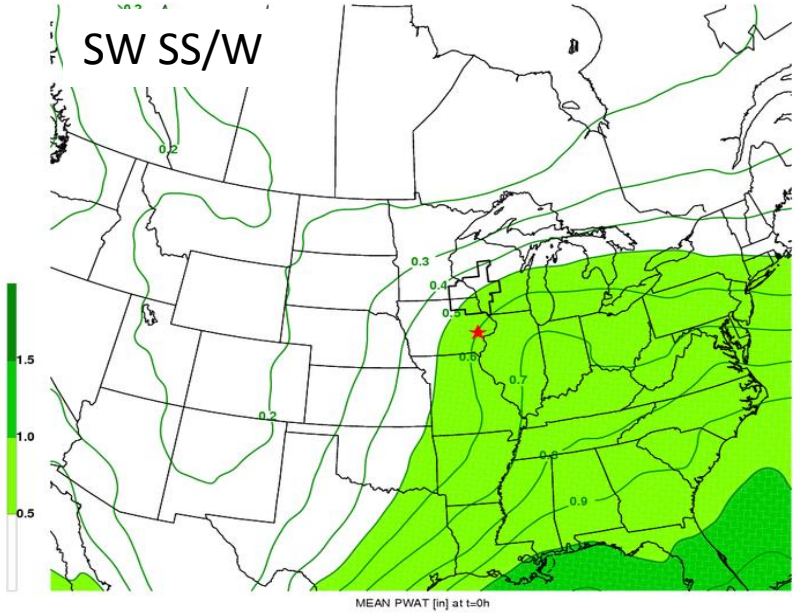
- NW: Up to 133% normal PW (0.30”).
- SW: Up to 200% normal PW.

- Moisture axis co-located with strongest forcing on heavy snow area.

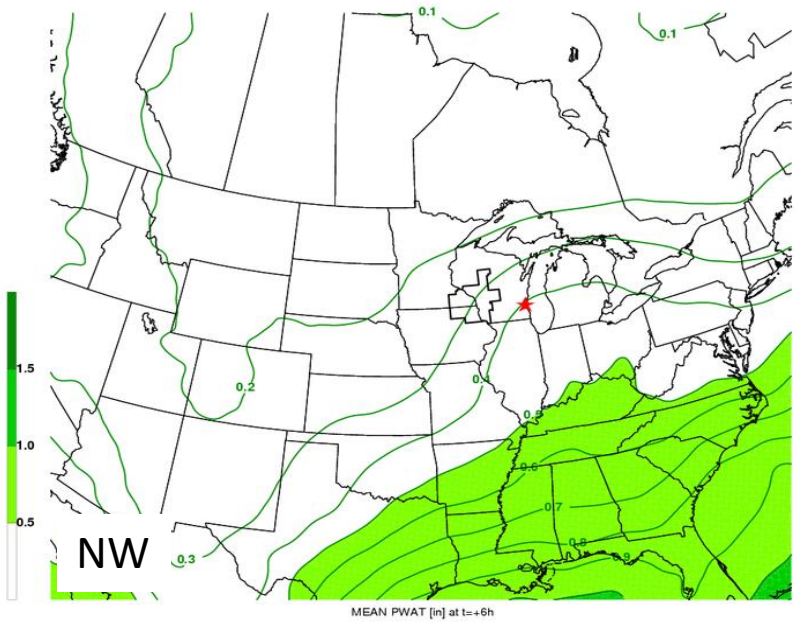
- SW D and SS/W similar moisture availability.

Precipitable Water (in.)





850mb Low indicated by “★“



Time:
T+6hrs
Heavy
Snow
End

- NW: Up to 133% normal PW (0.30”).
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- Moisture axis co-located with strongest forcing on heavy snow area.

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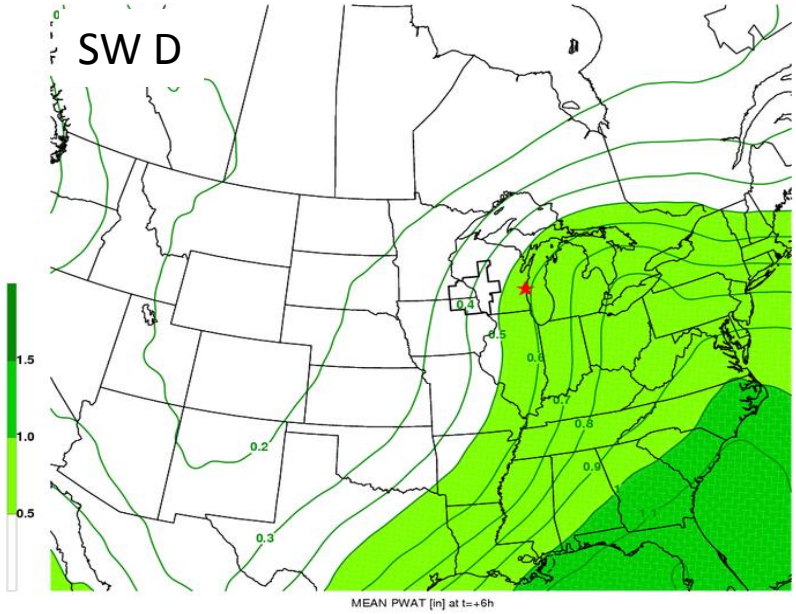
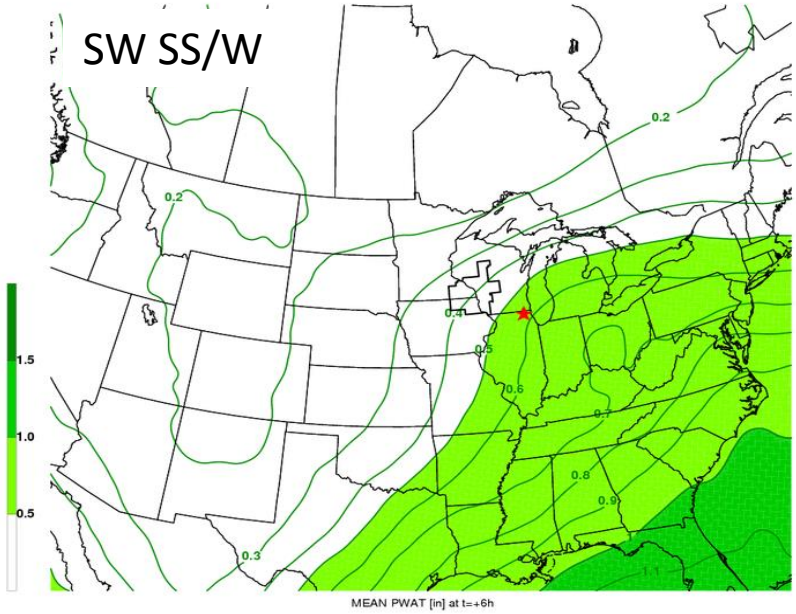
Precipitable Water (in.)





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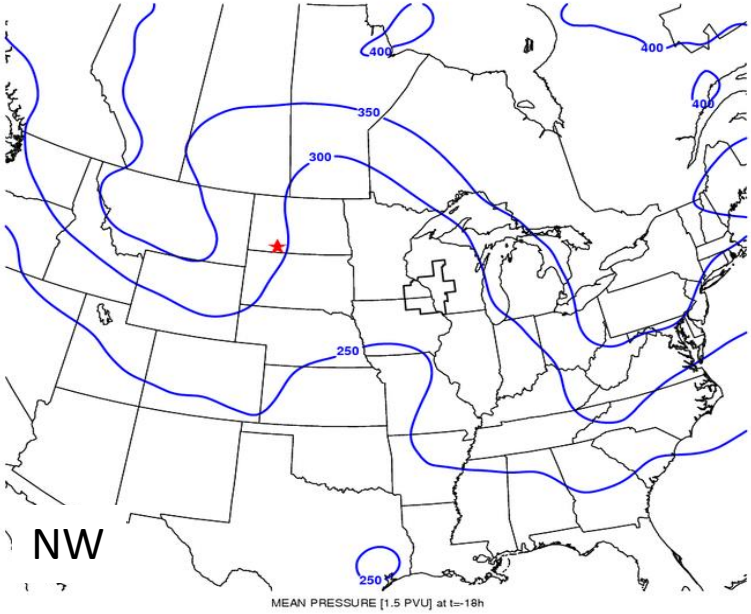
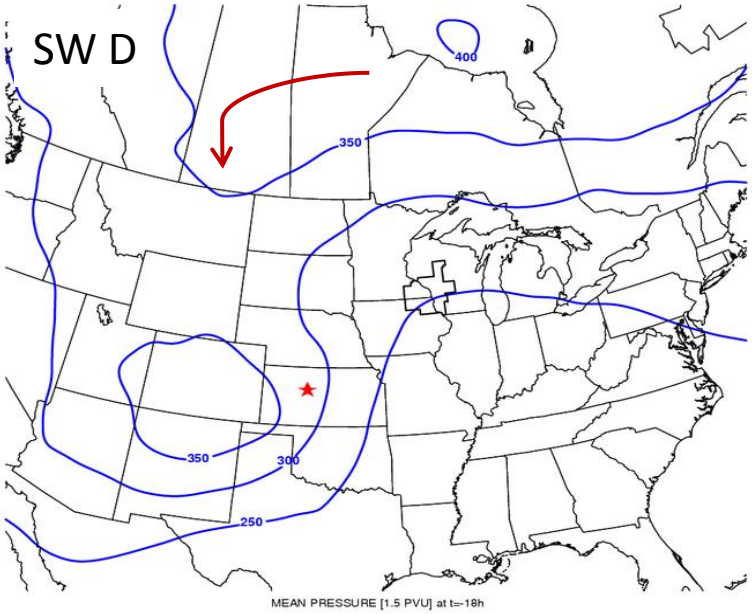
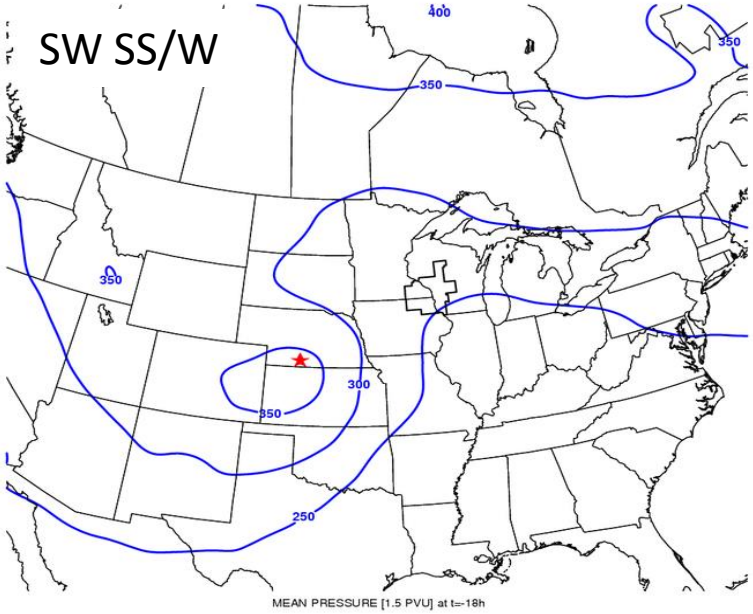


Time: t-6hrs Heavy Snow Begin

- 850mb low positioned under implied PV advection area.
- NW/SW D: Link to poleward PV source.
- SW D: Visualize the phasing of the poleward PV source with SW flow trop fold, deepening.
- Treble-cleft signature shows up late, with implied occlusion (Posselt and Martin, 2004).

Tropopause Pressure (1.5 PVU)





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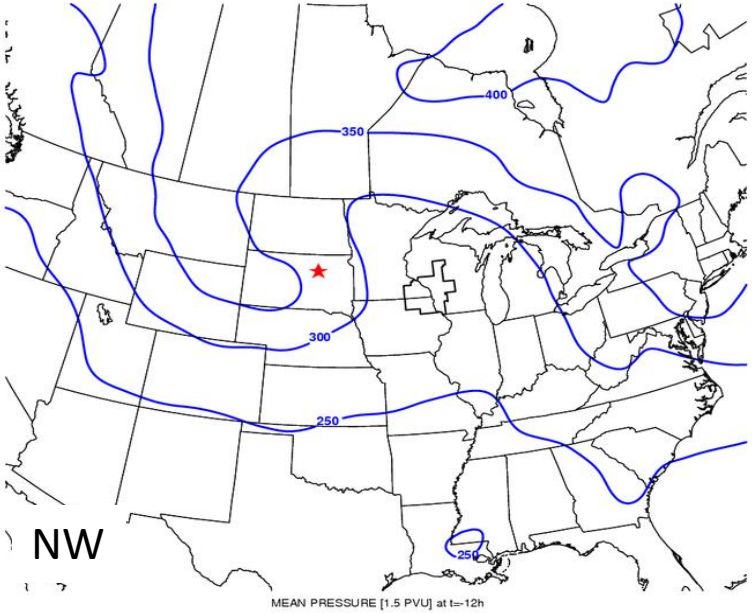

Time: Heavy Snow Begin (00h)

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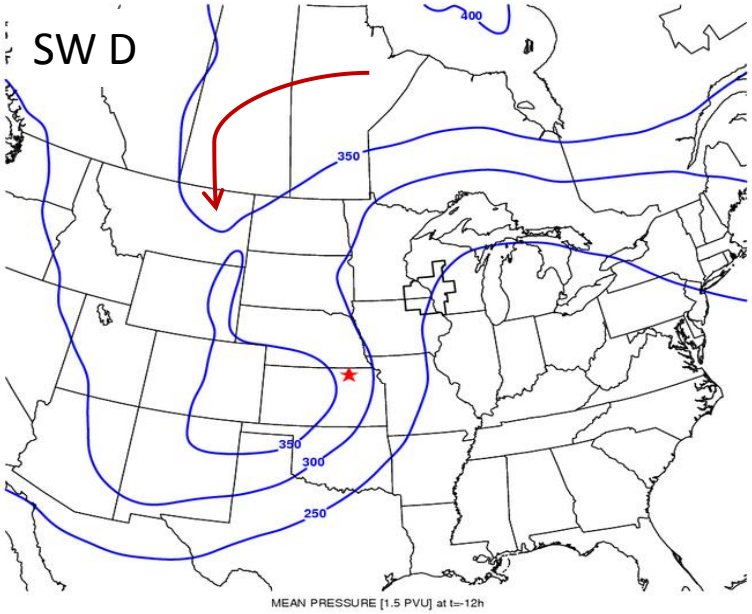

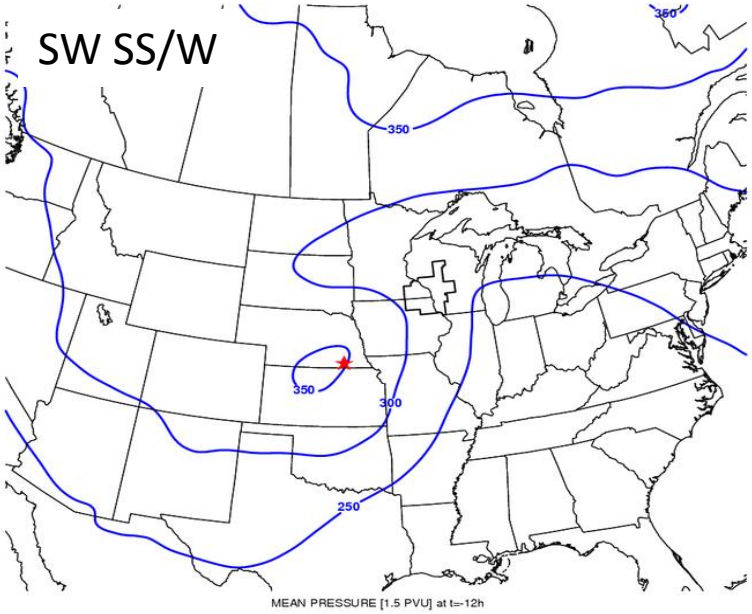

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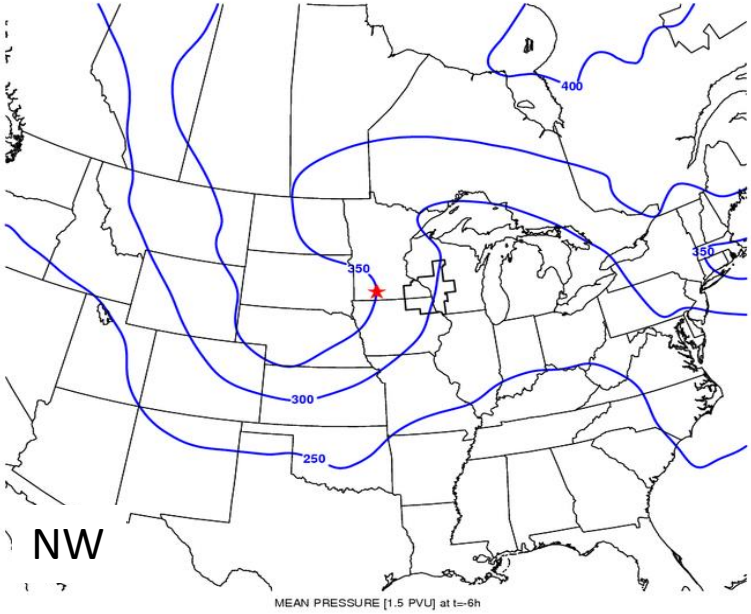

Time: Heavy Snow

(06h)

- 850mb low positioned under implied PV advection area.
- NW/SW D: Link to poleward PV source.
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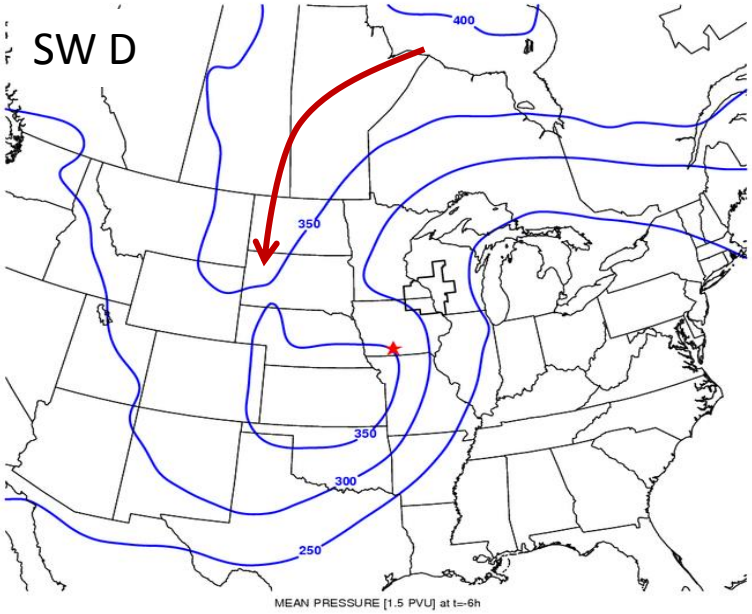
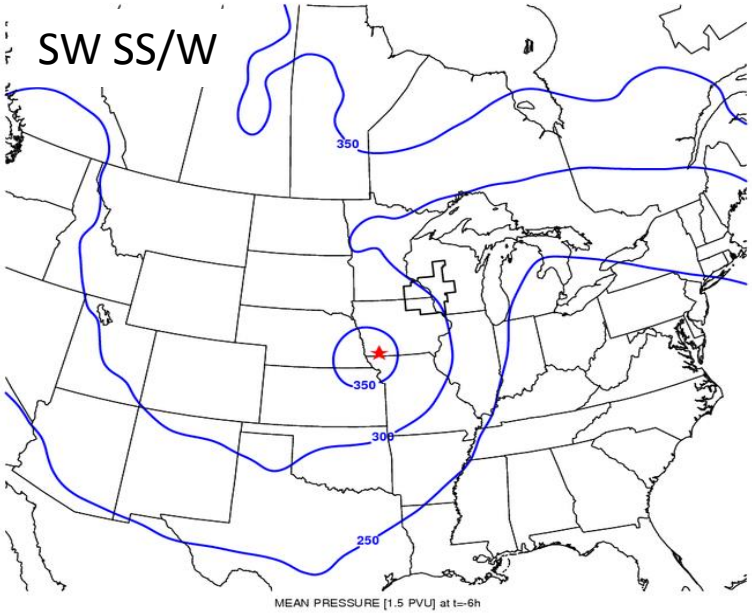
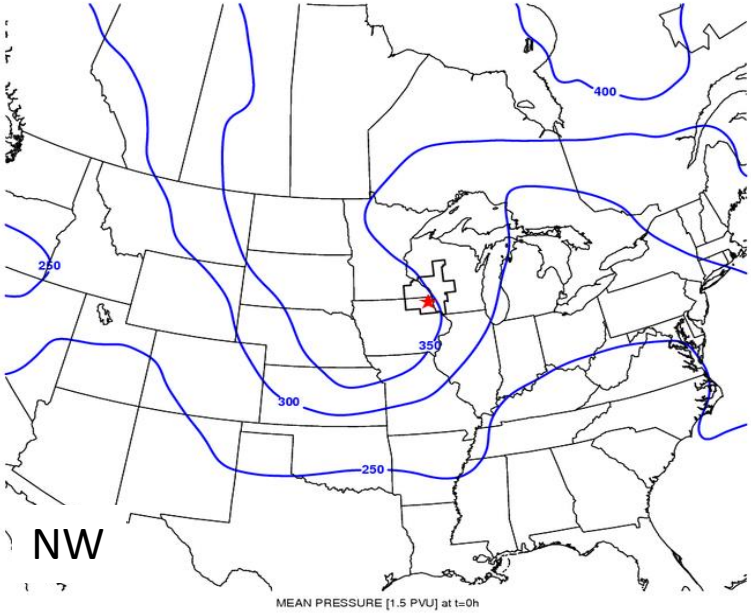
Tropopause Pressure (1.5 PVU)





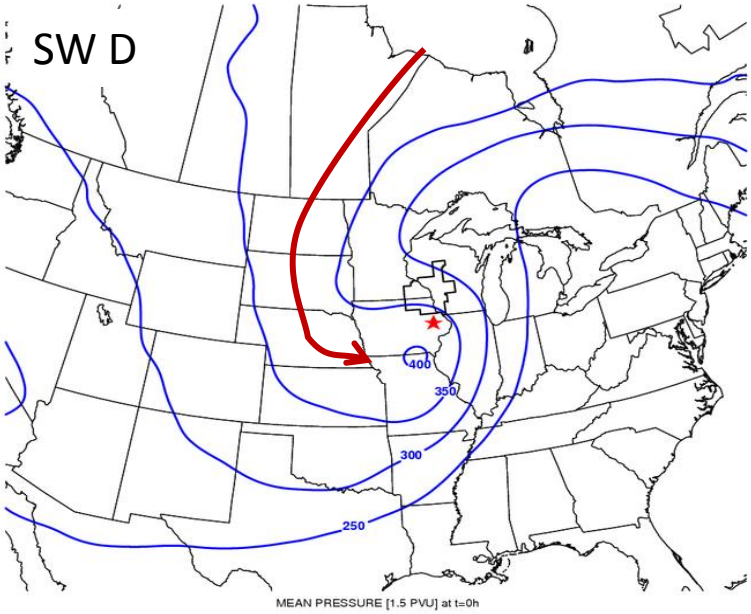
850mb Low indicated by "★"

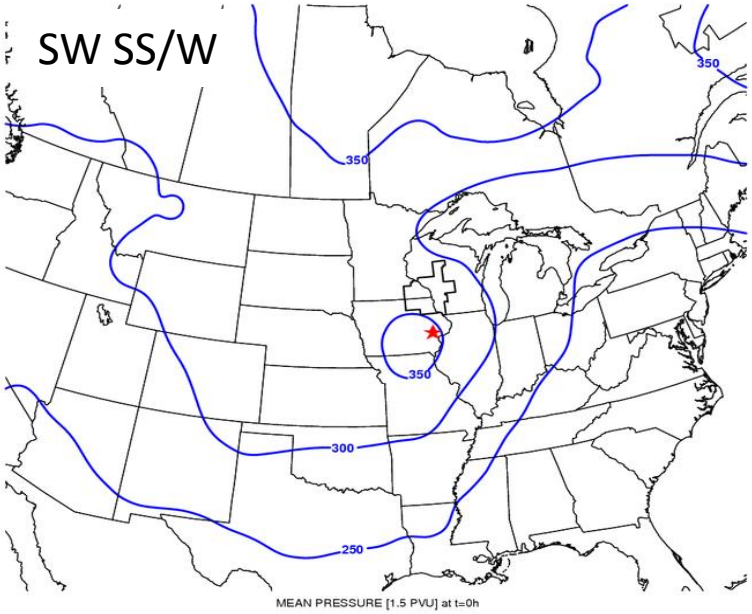


Time: Heavy Snow Ending (12h)

- 850mb low positioned under implied PV advection area.
- NW/SW D: Link to poleward PV source.
- SW D: Visualize the phasing of the poleward PV source with SW flow trop fold, deepening.
- Treble-cleft signature shows up late, with implied occlusion (Posselt and Martin, 2004).

Tropopause Pressure (1.5 PVU)





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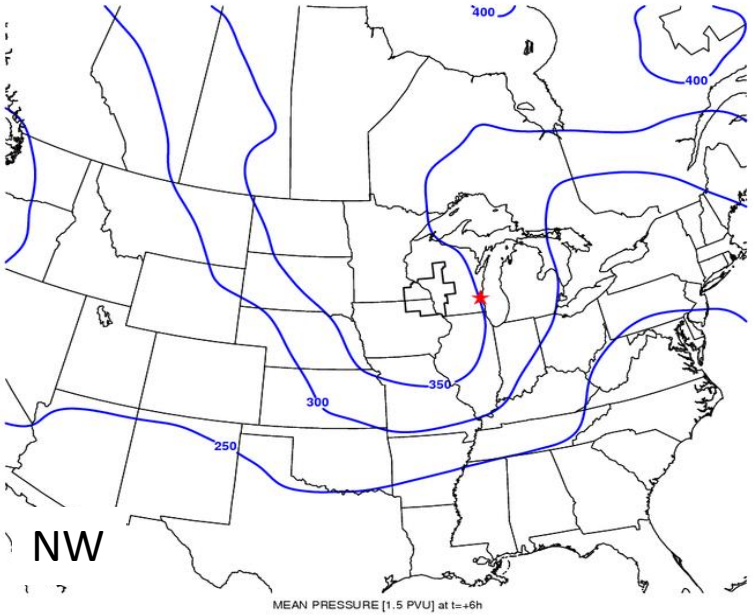

Time:
T+6hrs
Heavy
Snow
End

- 850mb low positioned under implied PV advection area.
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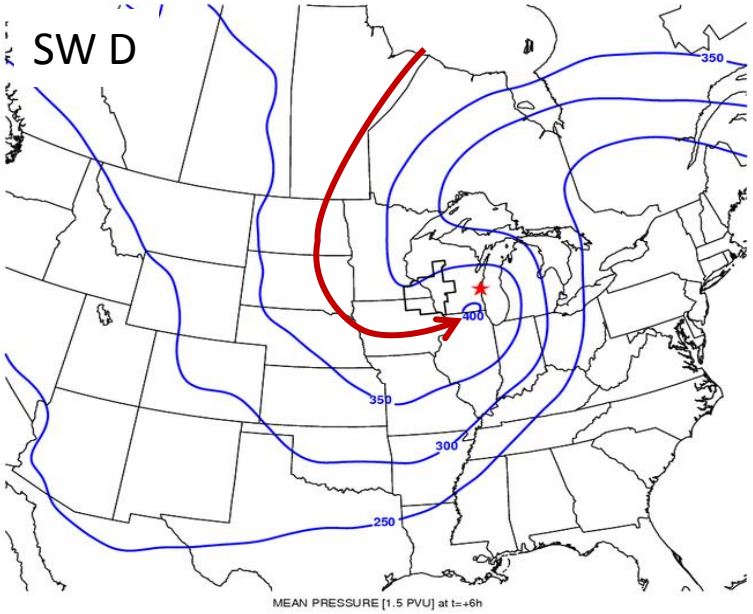
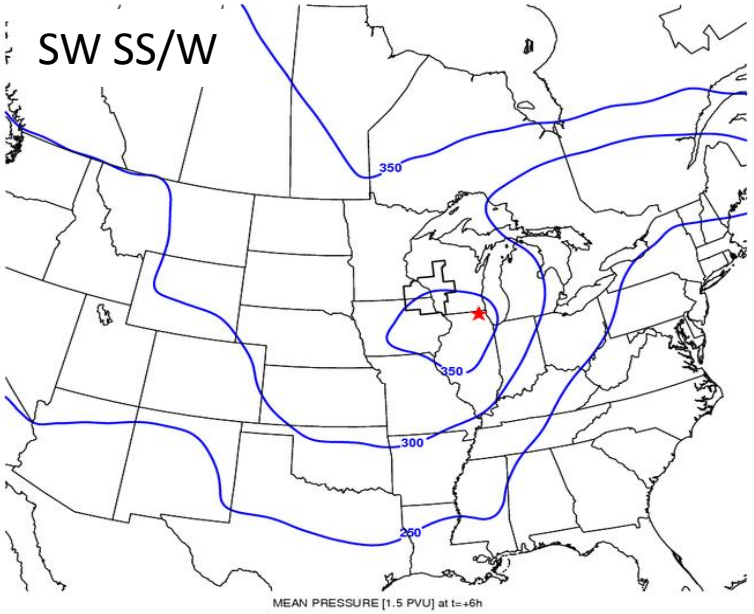
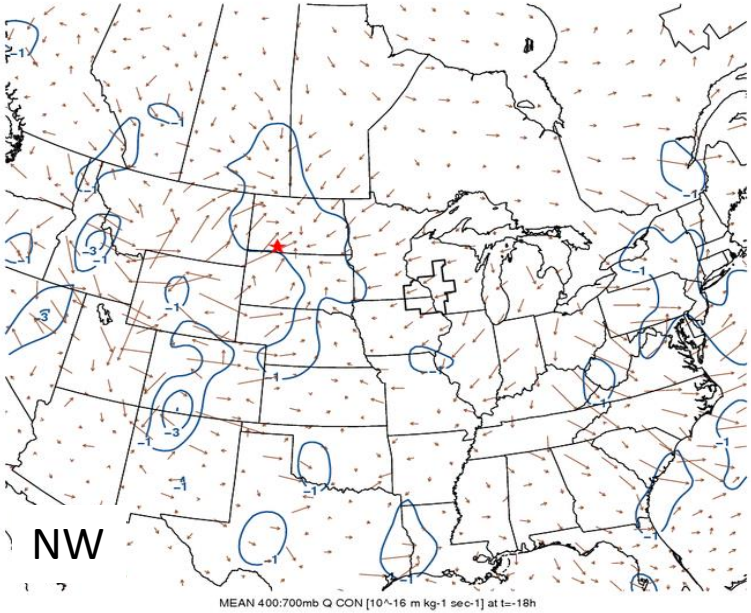
Tropopause Pressure (1.5 PVU)





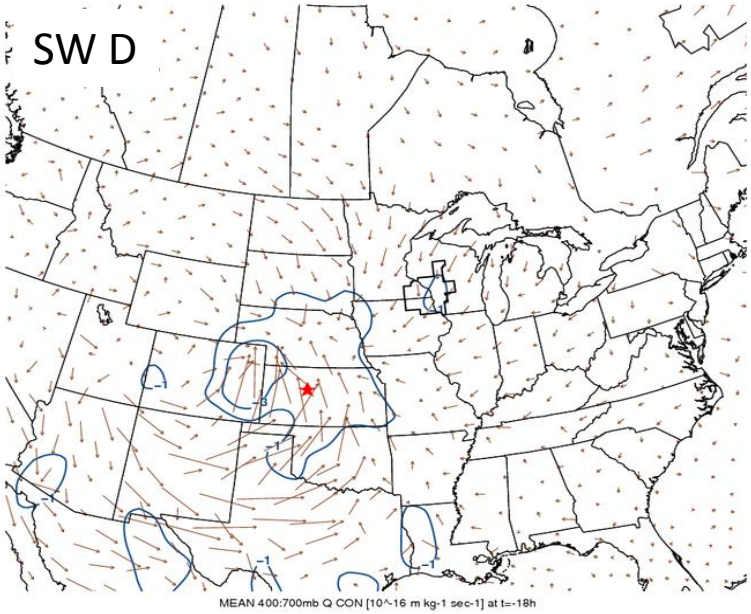
850mb Low indicated by "★"

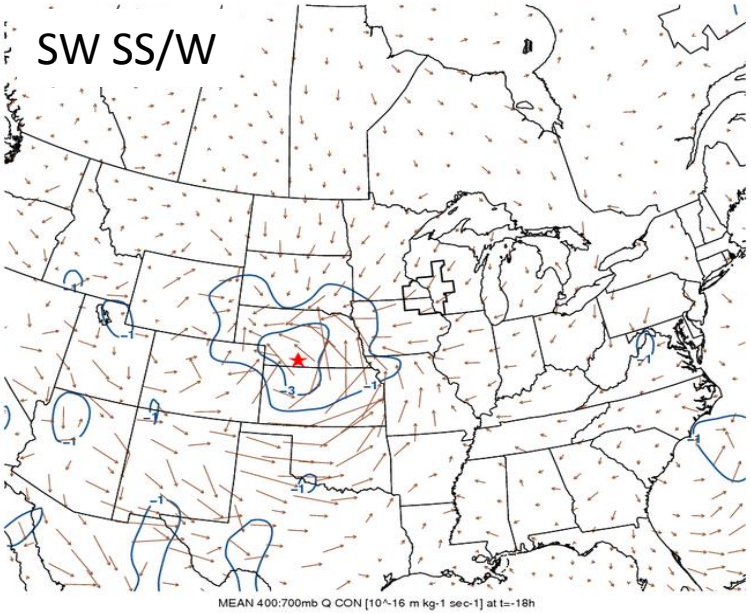


Time: t-6hrs Heavy Snow Begin

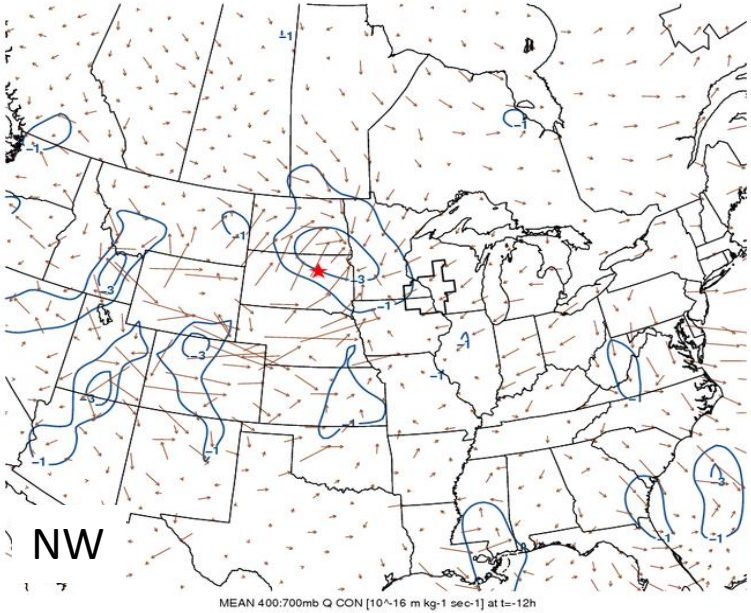
- Q-Vector convergence through mid-troposphere a direct hit on heavy snow area.
- SW: Intensifying on track.

400-700mb Q-vector Divergence (Convergence shown)





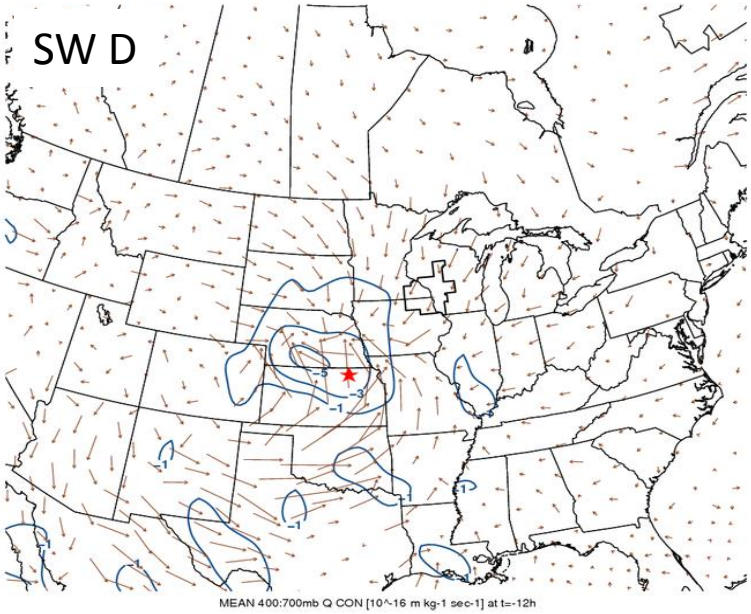
850mb Low indicated by "★"

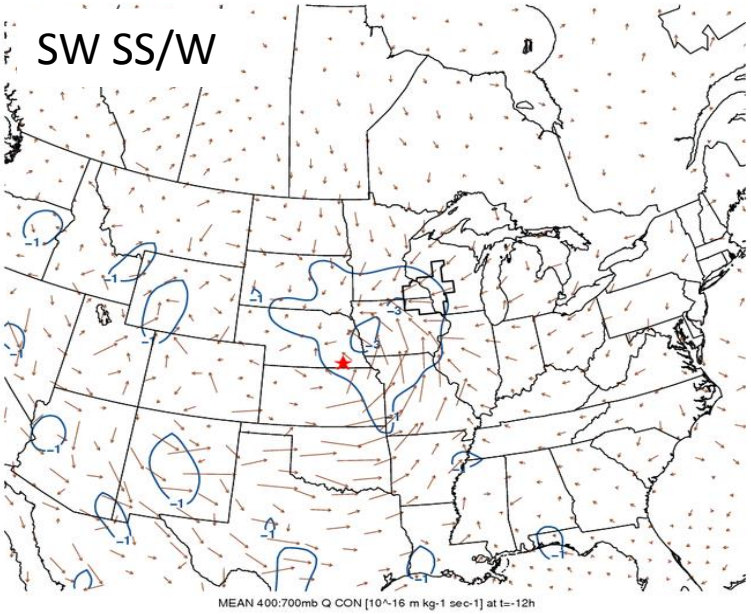


Time: Heavy Snow Begin (00h)

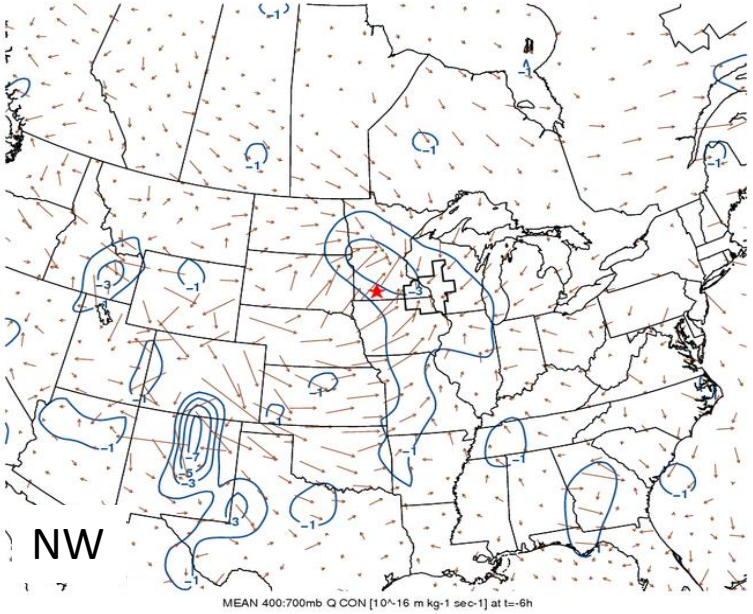
- Q-Vector convergence through mid-troposphere a direct hit on heavy snow area.
- SW: Intensifying on track.

400-700mb Q-vector Divergence (Convergence shown)





850mb Low indicated by "★"

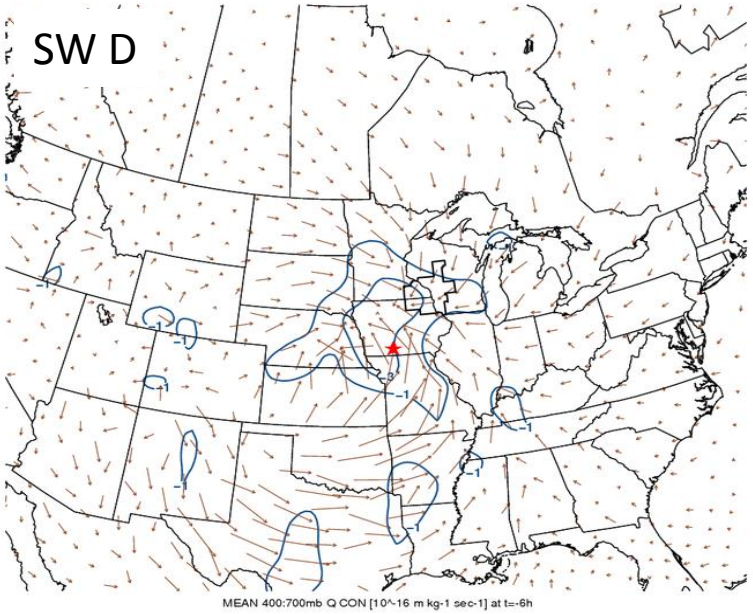


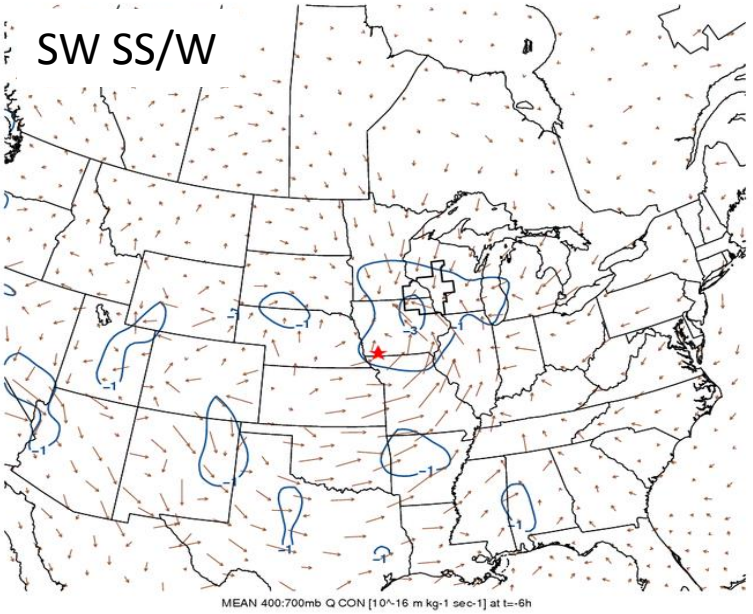
Time: Heavy Snow

(06h)

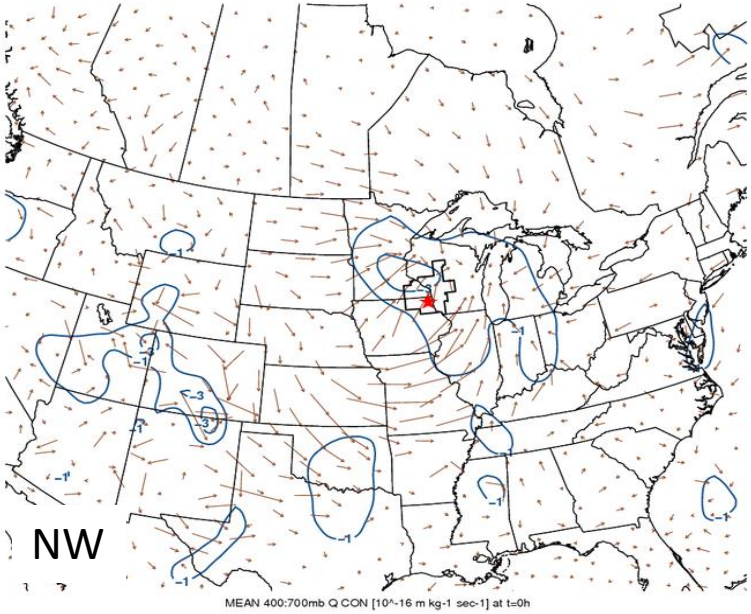
- Q-Vector convergence through mid-troposphere a direct hit on heavy snow area.
- SW: Intensifying on track.

400-700mb Q-vector Divergence (Convergence shown)





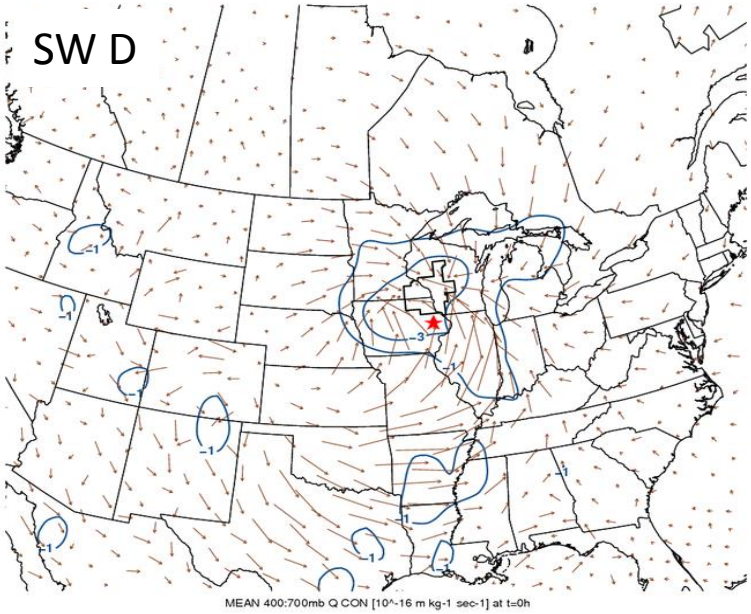
850mb Low indicated by "★"

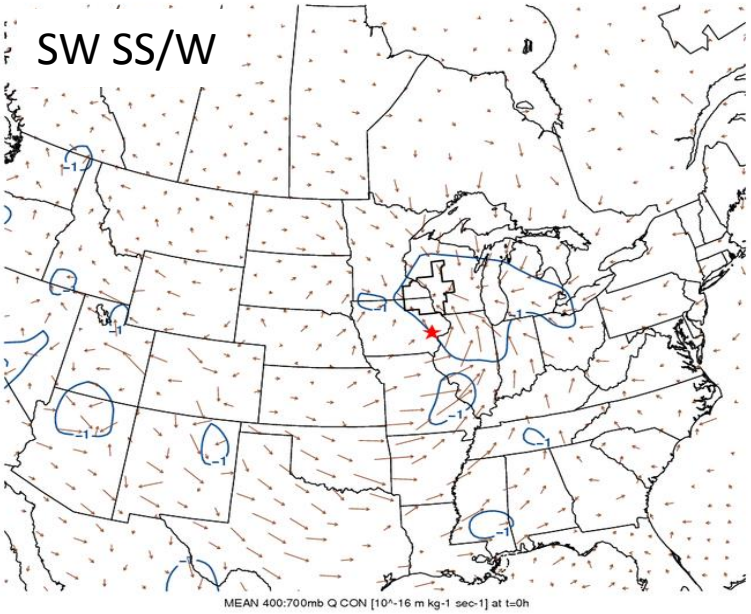


Time: Heavy Snow Ending (12h)

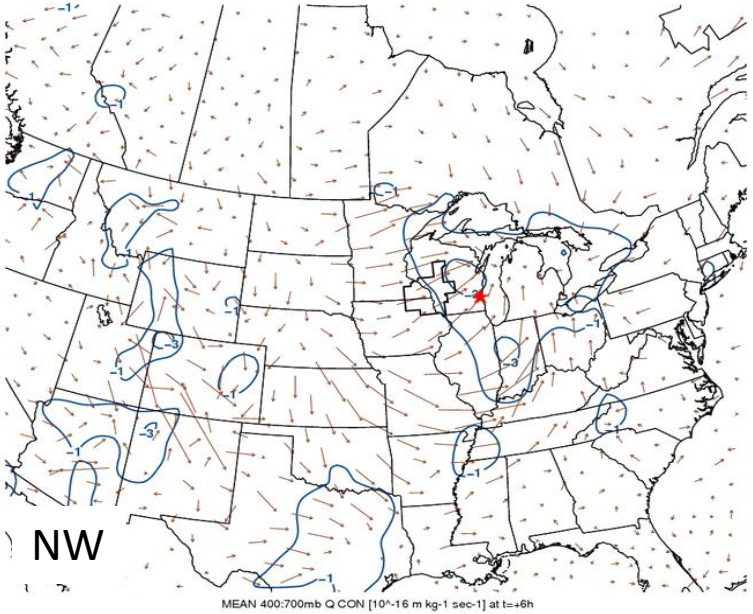
- Q-Vector convergence through mid-troposphere a direct hit on heavy snow area.
- SW: Intensifying on track.

400-700mb Q-vector Divergence (Convergence shown)





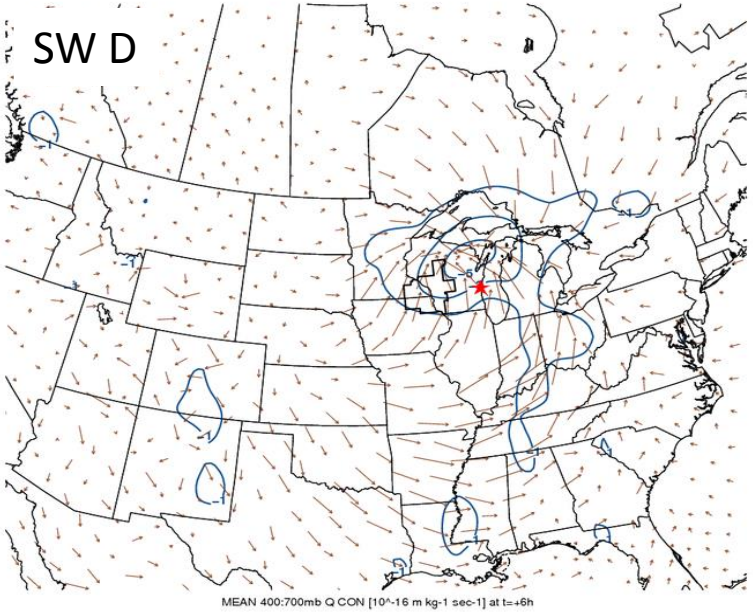
850mb Low indicated by "★"

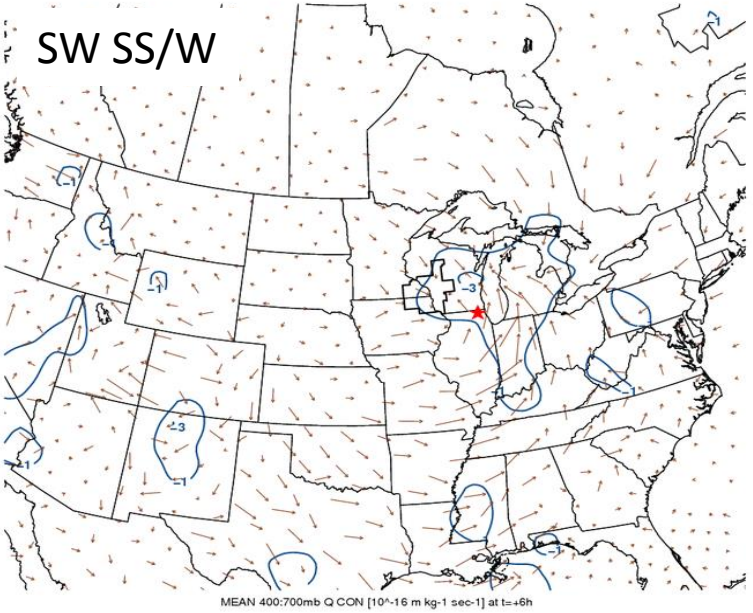


Time:
T+6hrs
Heavy
Snow
End

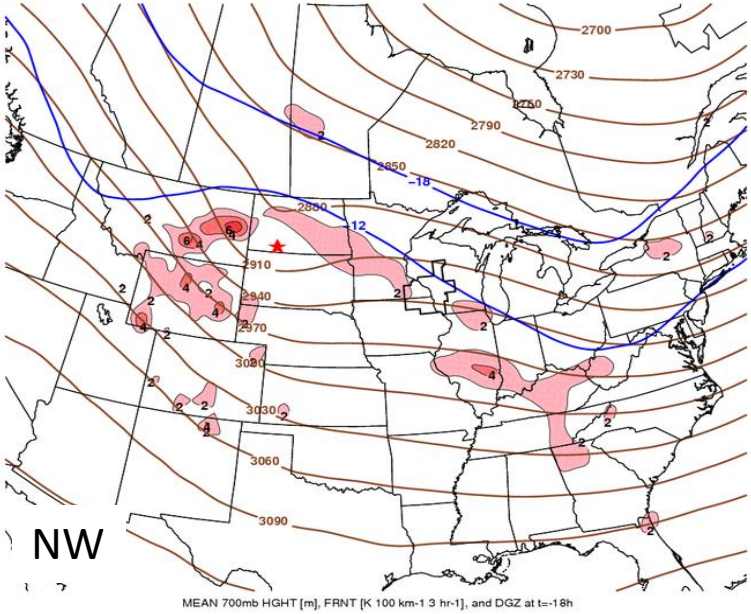
- Q-Vector convergence through mid-troposphere a direct hit on heavy snow area.
- SW: Intensifying on track.

400-700mb Q-vector Divergence (Convergence shown)





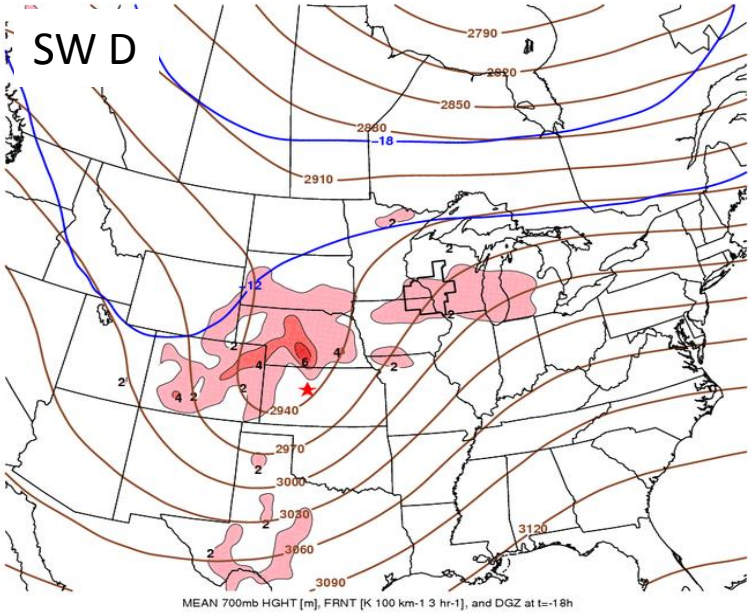
850mb Low indicated by "★"

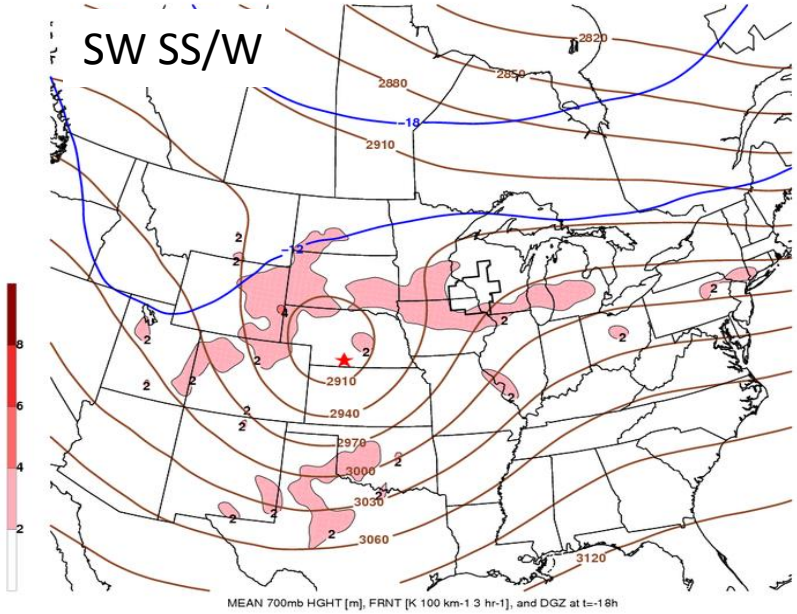


Time: t-6hrs Heavy Snow Begin

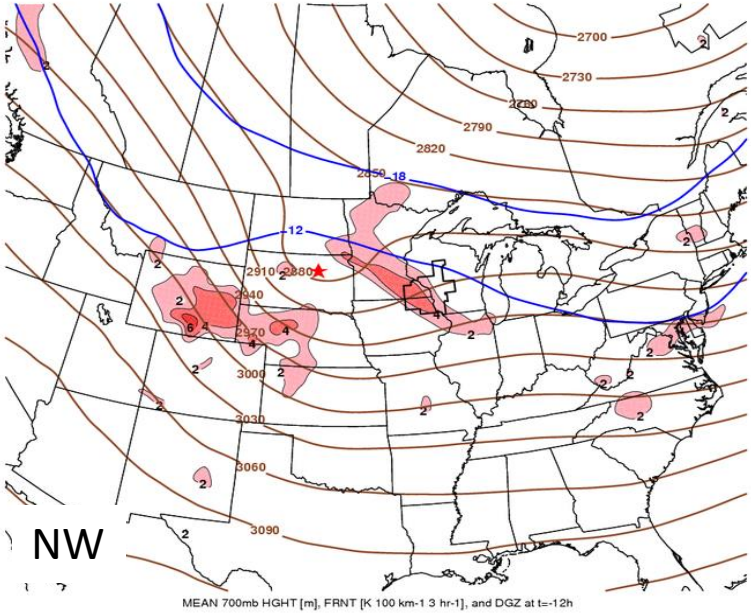
- ALL: Weak Fgen present early, downstream nearly 1000mi.
- ALL: Shortwave trough track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Focused signal, max at Heavy Snow Begin, -12C nearby for dendrite crystal growth influence.
- SW: Max during Heavy Snow period [06h] (6 K/100km 3 hr), Fgen lingers.

700mb Height, **Frontogenesis (red),** -12C and -18C Isotherms





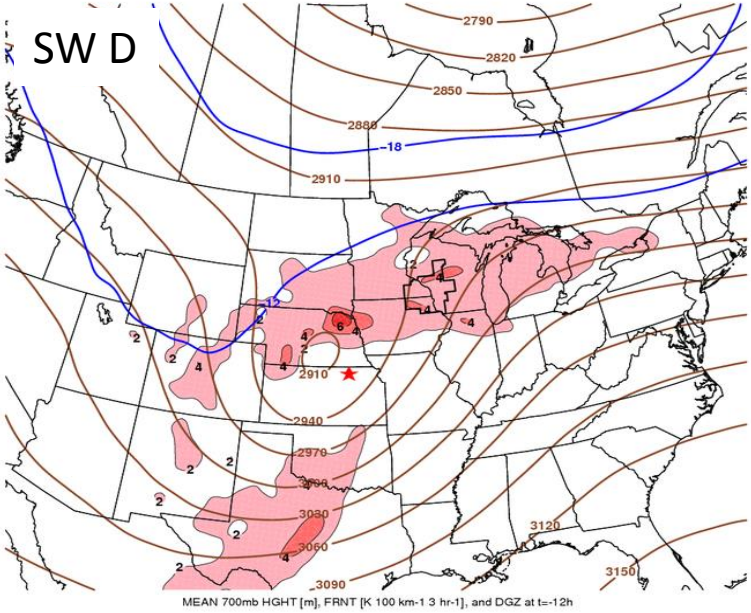
850mb Low indicated by "★"

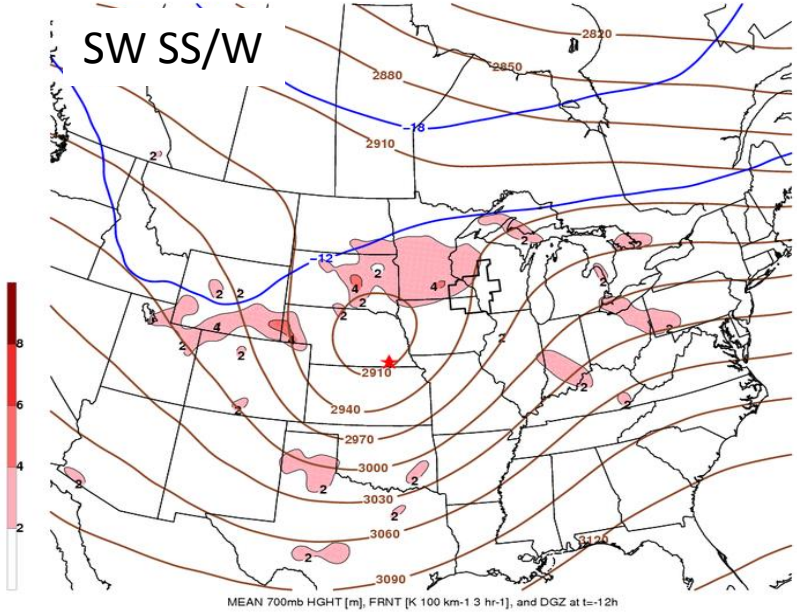


Time: Heavy Snow Begin (00h)

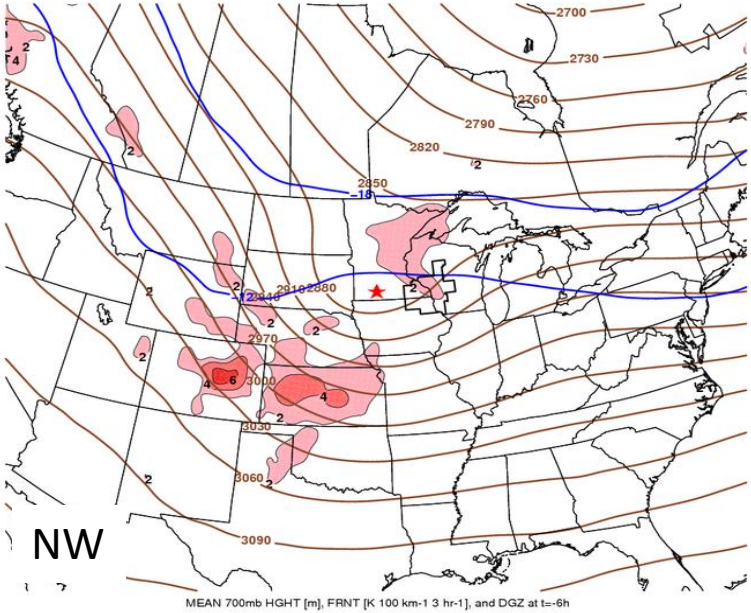
- ALL: Weak Fgen present early, downstream nearly 1000mi.
- ALL: Shortwave trough track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Focused signal, max at Heavy Snow Begin, -12C nearby for dendrite crystal growth influence.
- SW: Max during Heavy Snow period [06h] (6 K/100km 3 hr), Fgen lingers.

700mb Height, **Frontogenesis (red),** -12C and -18C Isotherms





850mb Low indicated by "★"

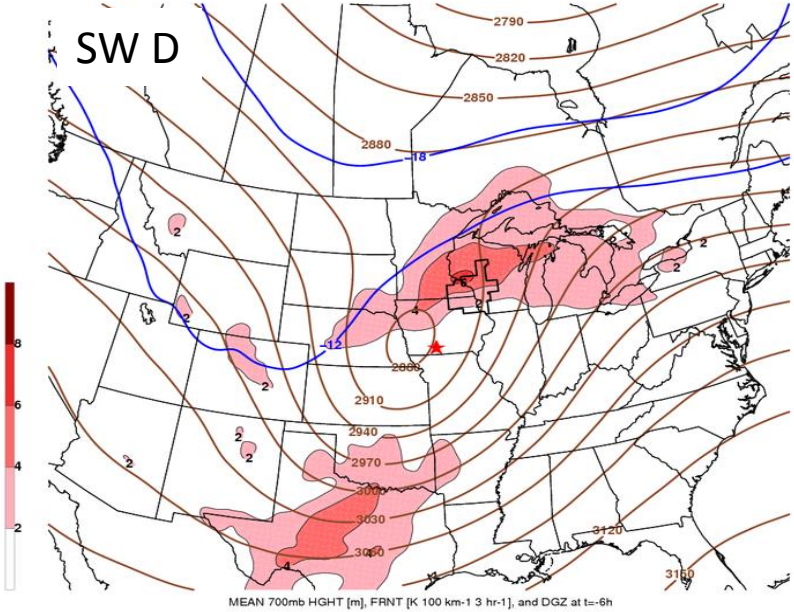


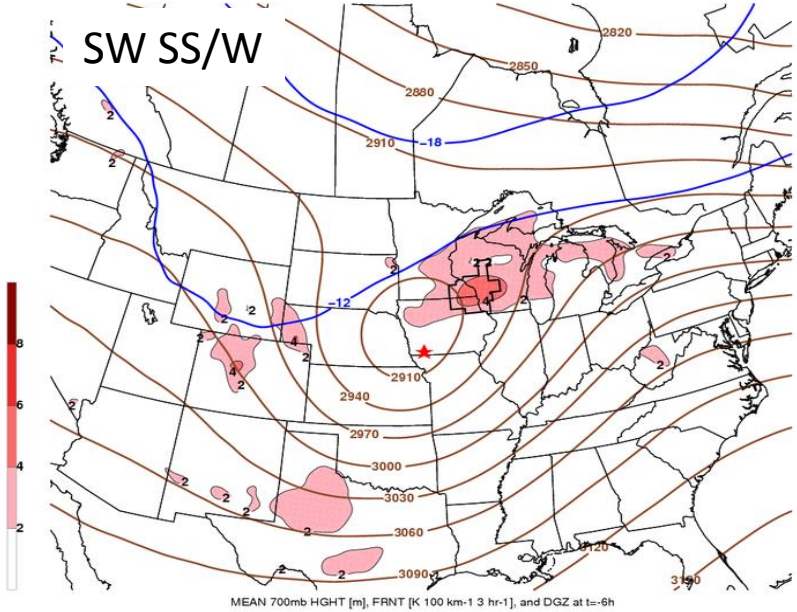
Time: Heavy Snow

(06h)

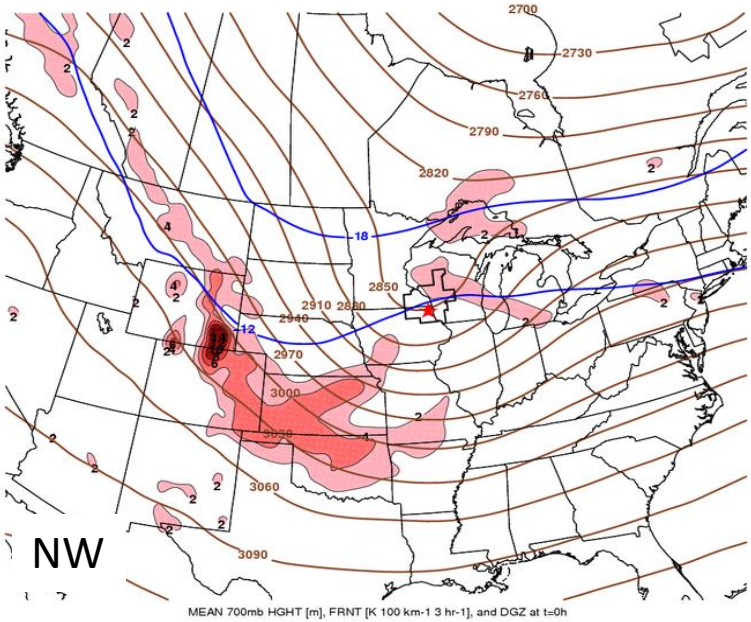
- ALL: Weak Fgen present early, downstream nearly 1000mi.
- ALL: Shortwave trough track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Focused signal, max at Heavy Snow Begin, -12C nearby for dendrite crystal growth influence.
- SW: Max during Heavy Snow period [06h] (6 K/100km 3 hr), Fgen lingers.

700mb Height, **Frontogenesis (red),** -12C and -18C Isotherms





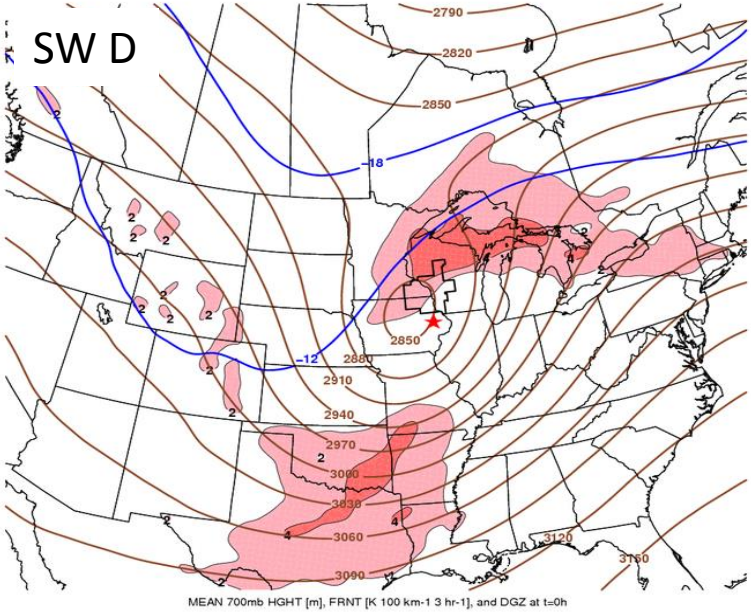
850mb Low indicated by "★"

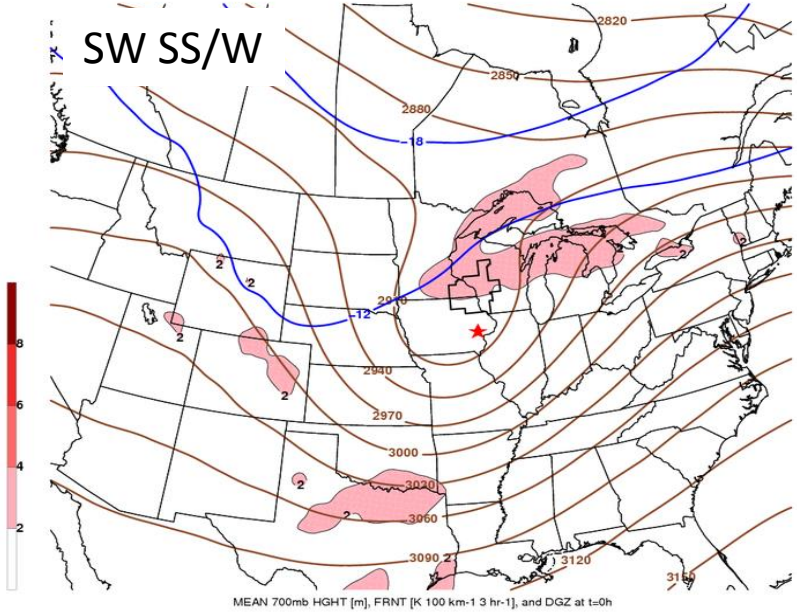


Time: Heavy Snow Ending (12h)

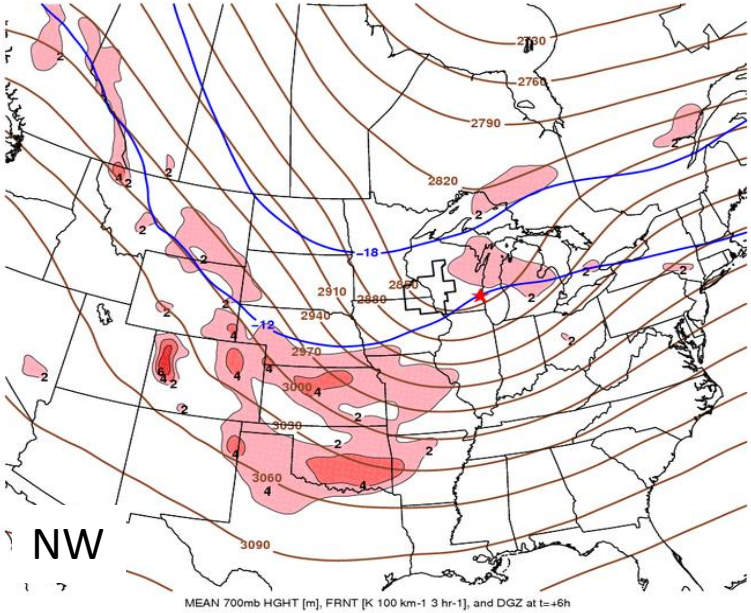
- ALL: Weak Fgen present early, downstream nearly 1000mi.
- ALL: Shortwave trough track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Focused signal, max at Heavy Snow Begin, -12C nearby for dendrite crystal growth influence.
- SW: Max during Heavy Snow period [06h] (6 K/100km 3 hr), Fgen lingers.

700mb Height, **Frontogenesis (red),** -12C and -18C Isotherms





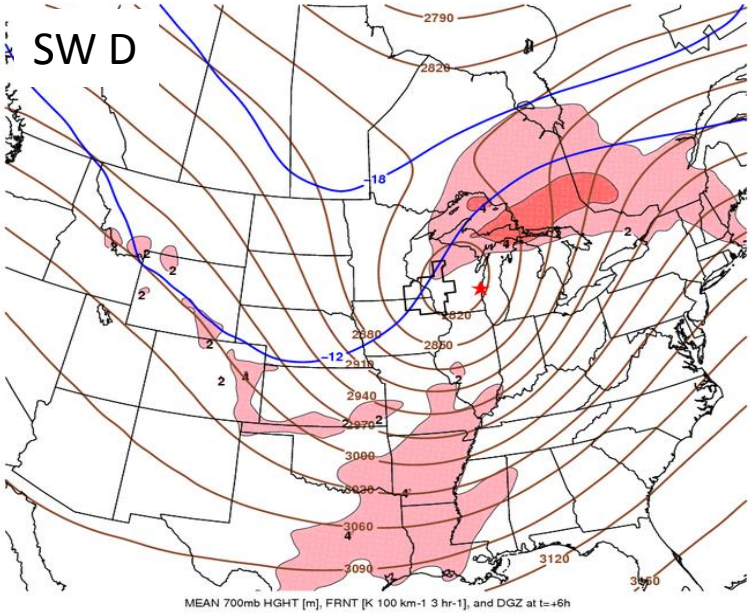
850mb Low indicated by "★"

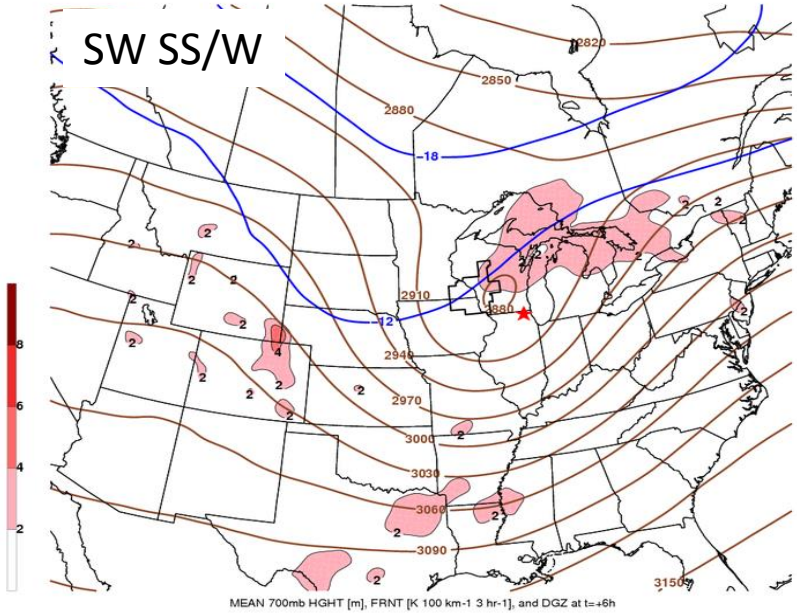


Time: T+6hrs Heavy Snow End

- ALL: Weak Fgen present early, downstream nearly 1000mi.
- ALL: Shortwave trough track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Focused signal, max at Heavy Snow Begin, -12C nearby for dendrite crystal growth influence.
- SW: Max during Heavy Snow period [06h] (6 K/100km 3 hr), Fgen lingers.

700mb Height, **Frontogenesis (red),** -12C and -18C Isotherms

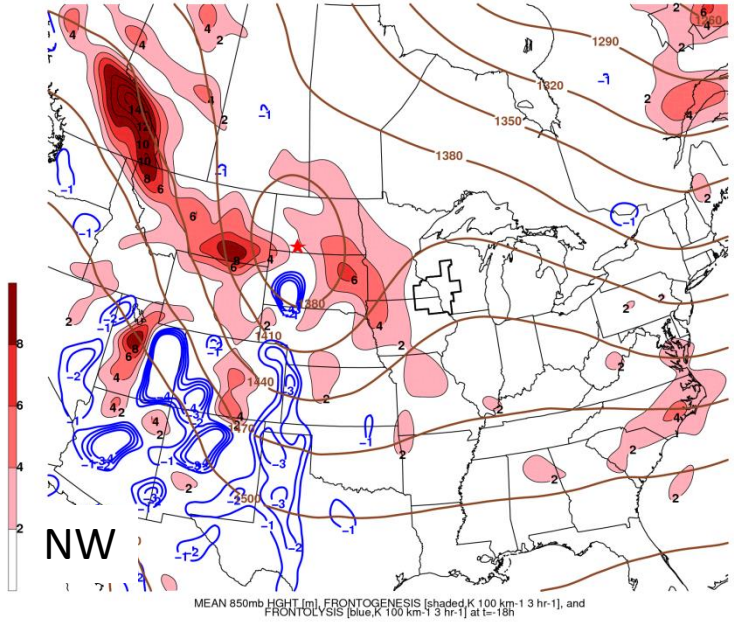




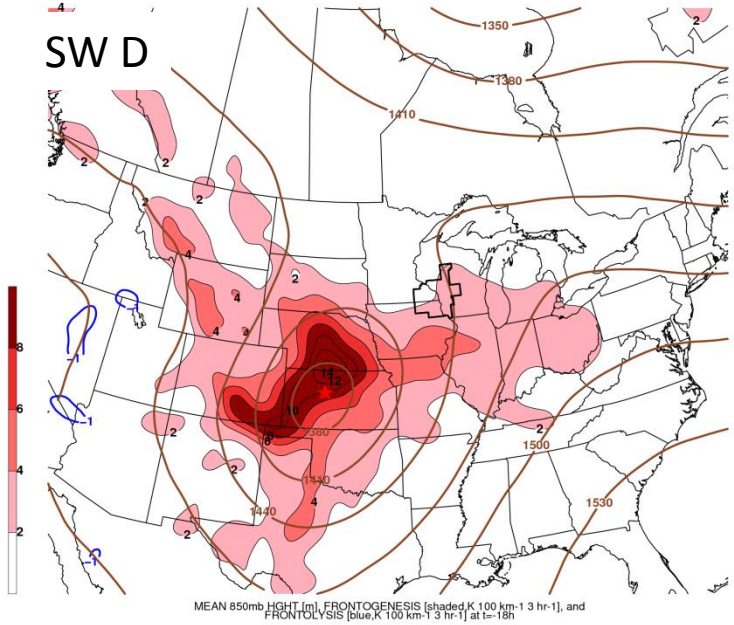
850mb Low indicated by "★"

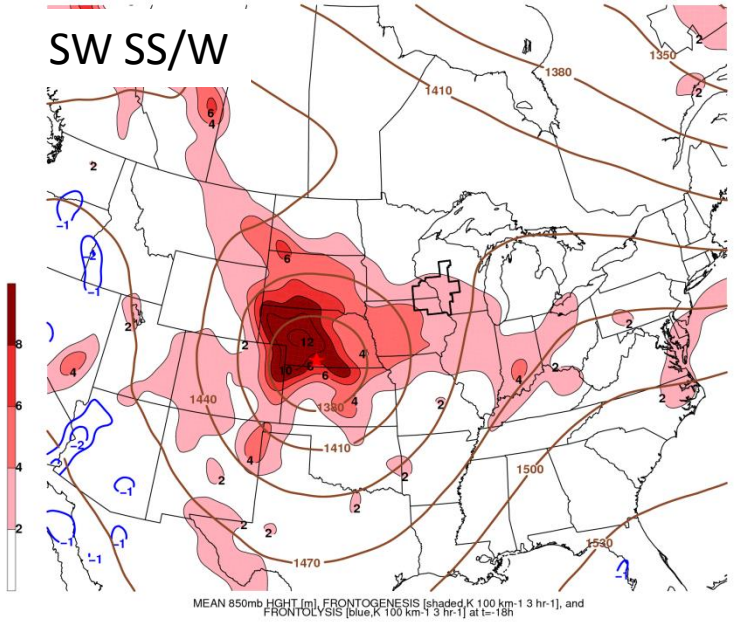
Time: t-6hrs Heavy Snow Begin

- ALL: Frontogenesis max transverses the area.
- ALL: Low track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Strong frontolysis signal shows up.
- SW: Max at Heavy Snow period (8 K/100km 3 hr), Fgen lingers.



850mb Height, **Frontogenesis (red),** Frontolysis (blue)

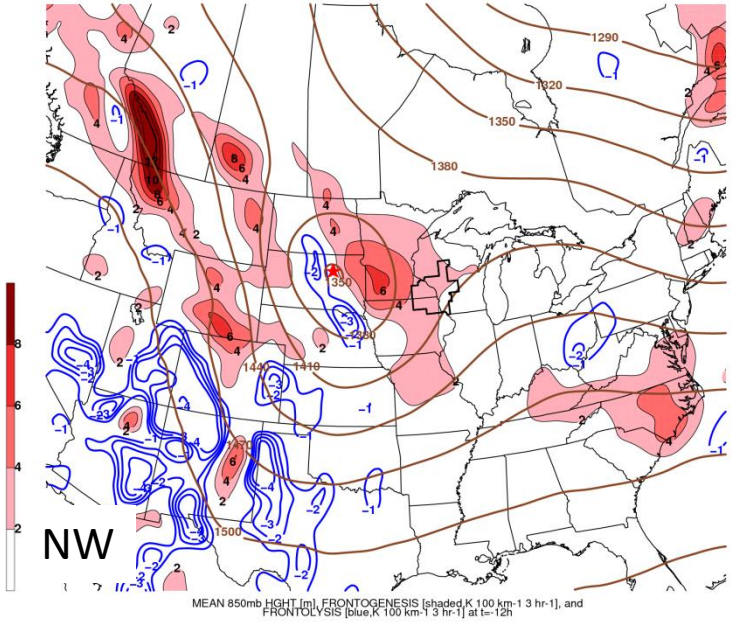




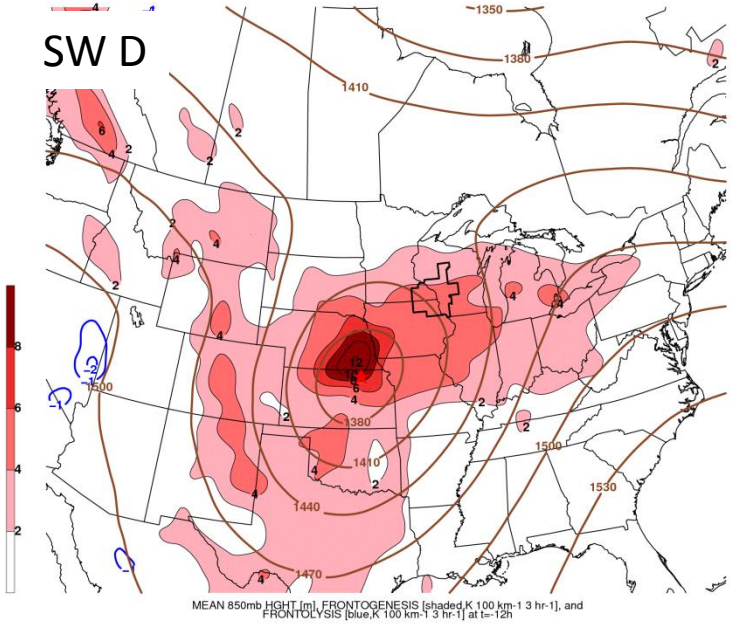
850mb Low indicated by "★"

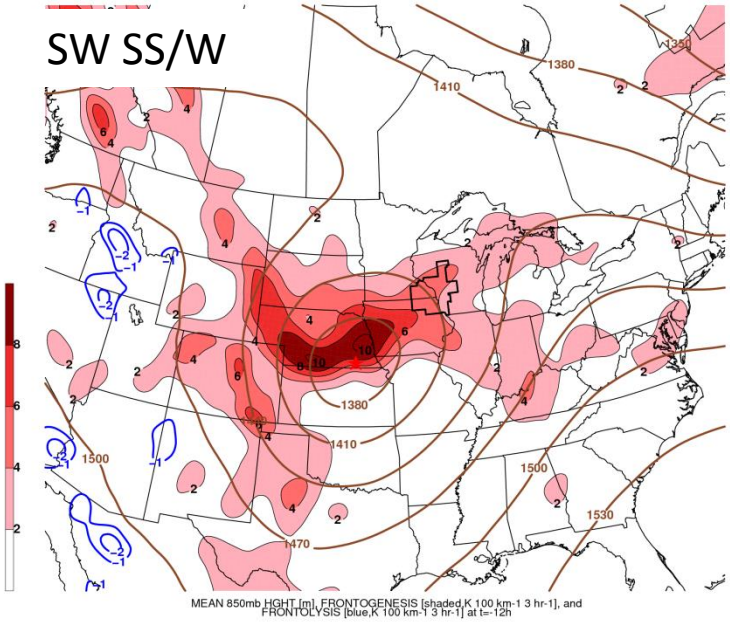
Time: Heavy Snow Begin (00h)

- ALL: Frontogenesis max transverses the area.
- ALL: Low track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Strong frontolysis signal shows up.
- SW: Max at Heavy Snow period (8 K/100km 3 hr), Fgen lingers.



850mb Height, **Frontogenesis (red),** Frontolysis (blue)





850mb Low indicated by "★"

Time: Heavy Snow

(06h)

- ALL: Frontogenesis max transverses the area.
- ALL: Low track parallel to frontogenesis orientation: duration of lift maximized.
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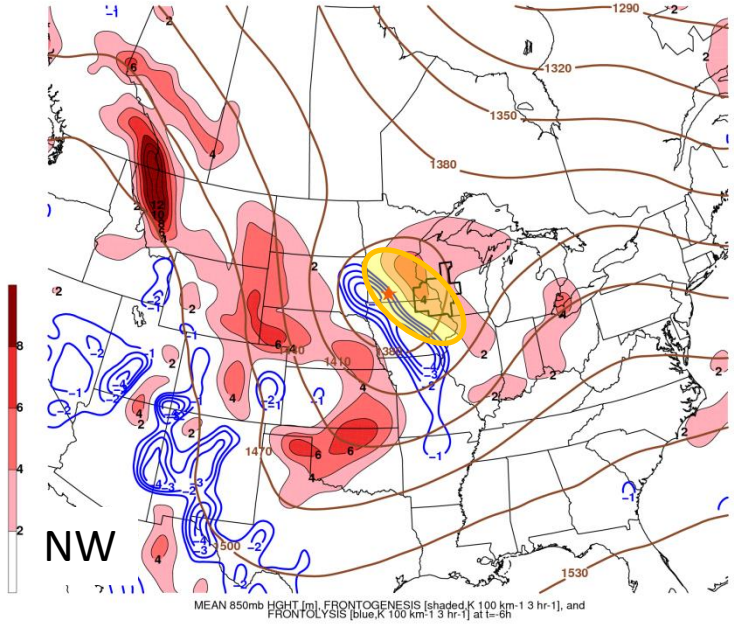
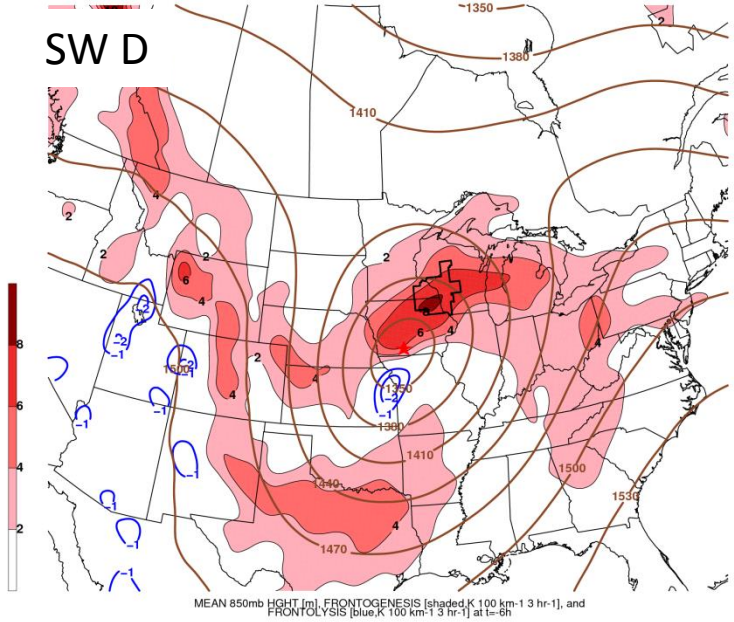
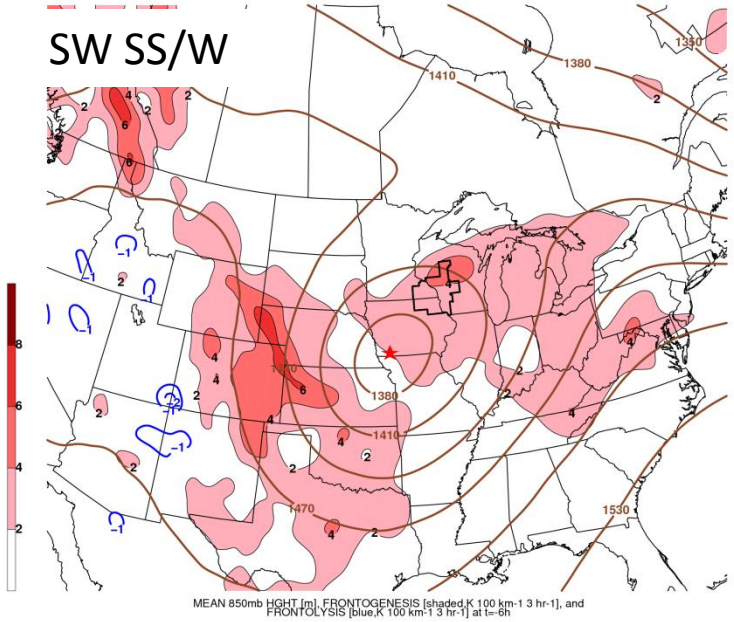


850mb Height, **Frontogenesis (red),** Frontolysis (blue)

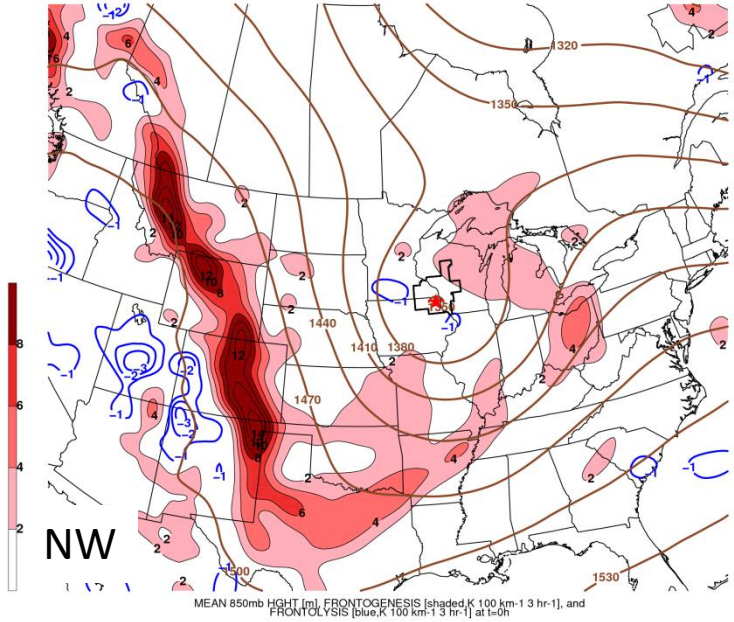




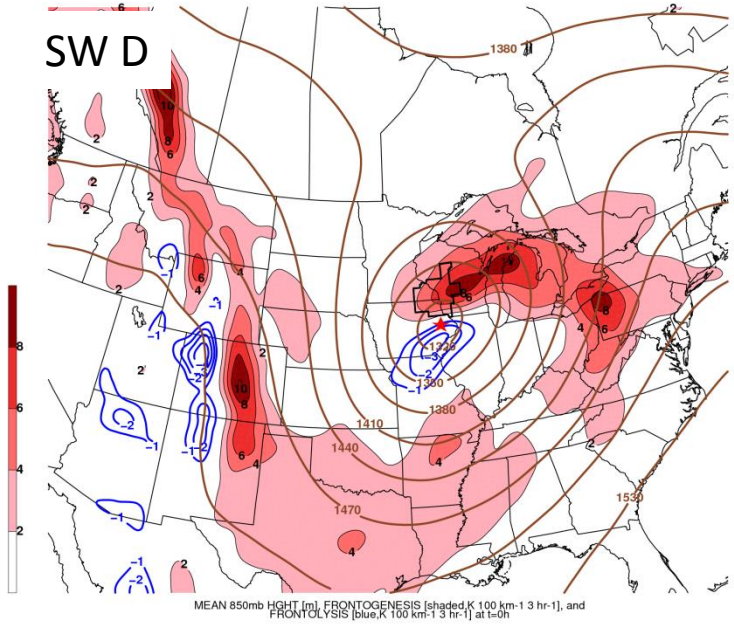
850mb Low indicated by "★"

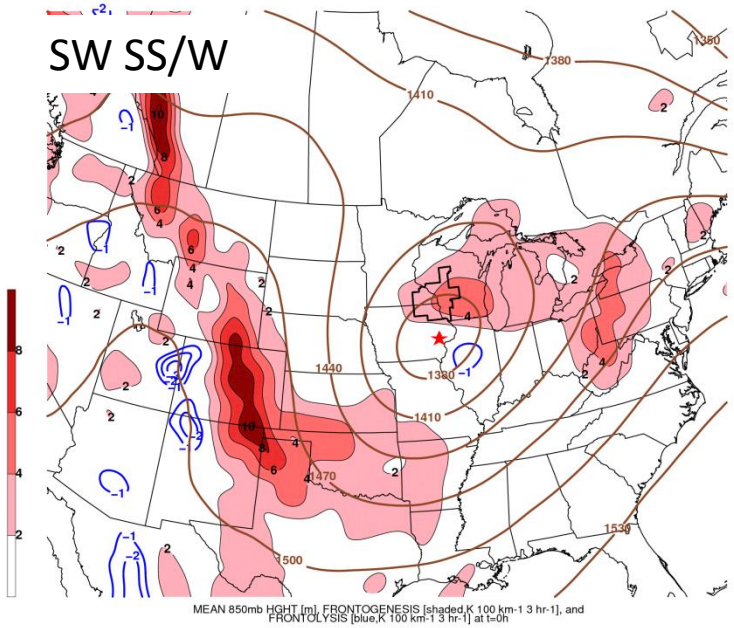
Time: Heavy Snow Ending (12h)

- ALL: Frontogenesis max transverses the area.
- ALL: Low track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Strong frontolysis signal shows up.
- SW: Max at Heavy Snow period (8 K/100km 3 hr), Fgen lingers.



850mb Height, **Frontogenesis (red),** Frontolysis (blue)

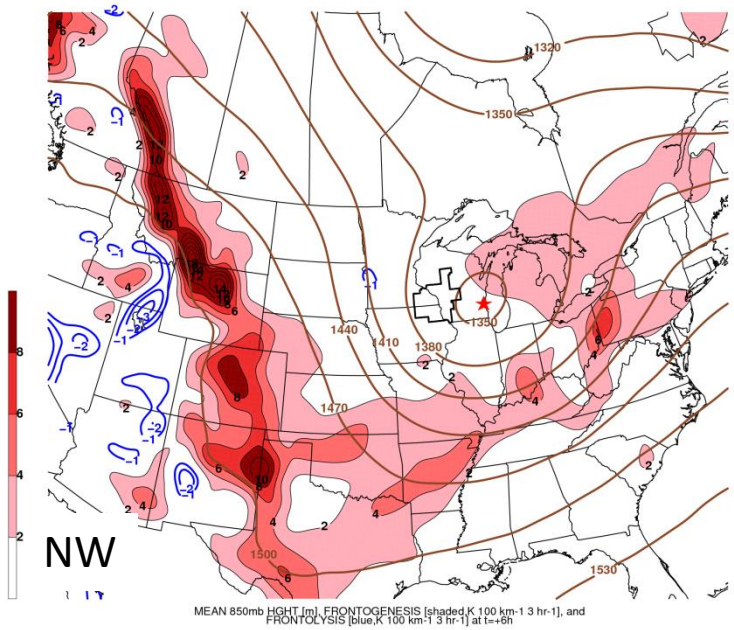




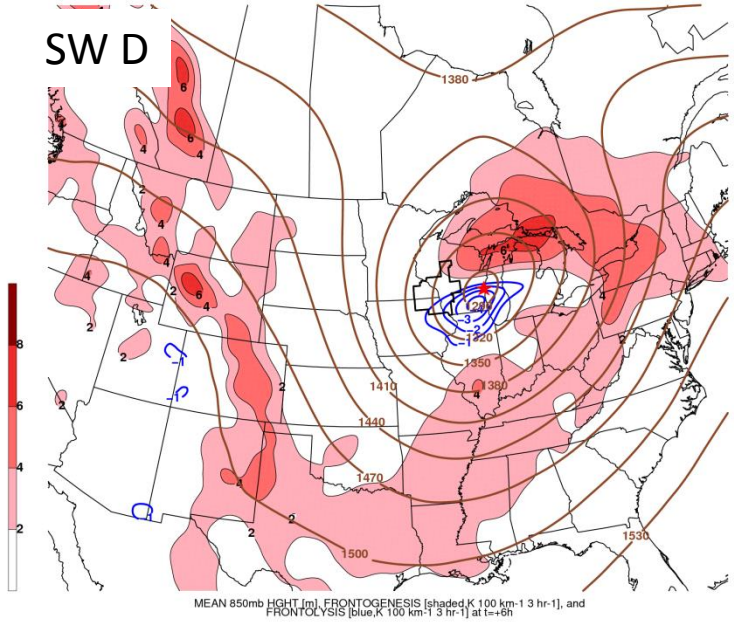
850mb Low indicated by "★"

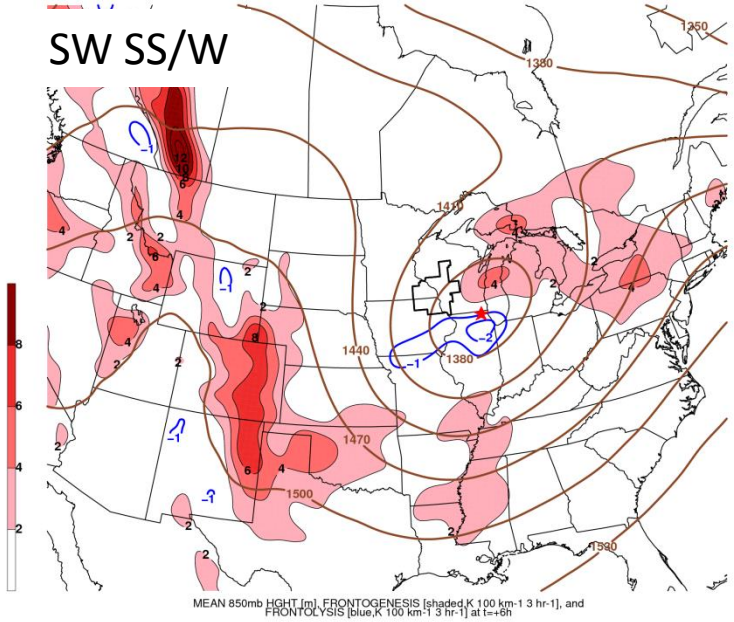
Time: T+6hrs Heavy Snow End

- ALL: Frontogenesis max transverses the area.
- ALL: Low track parallel to frontogenesis orientation: duration of lift maximized.
- NW: Strong frontolysis signal shows up.
- SW: Max at Heavy Snow period (8 K/100km 3 hr), Fgen lingers.

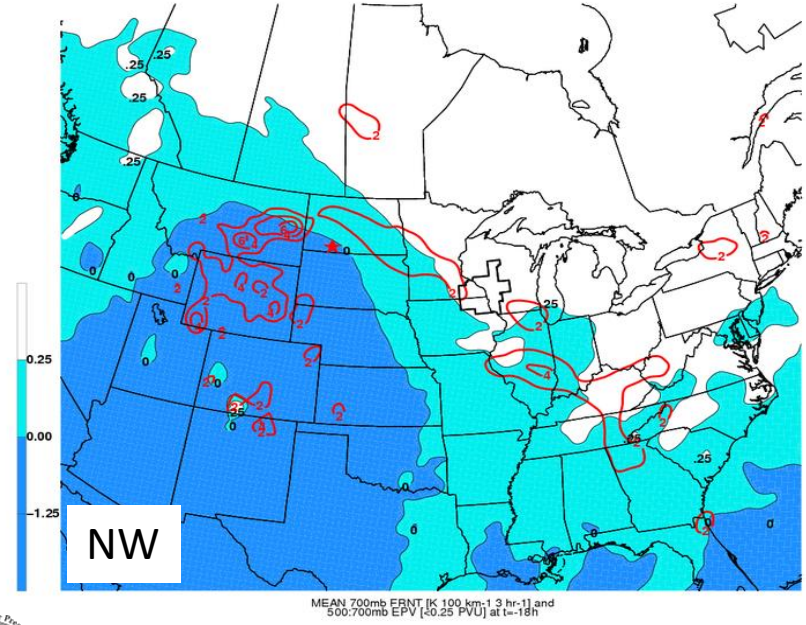


850mb Height, **Frontogenesis (red),** Frontolysis (blue)





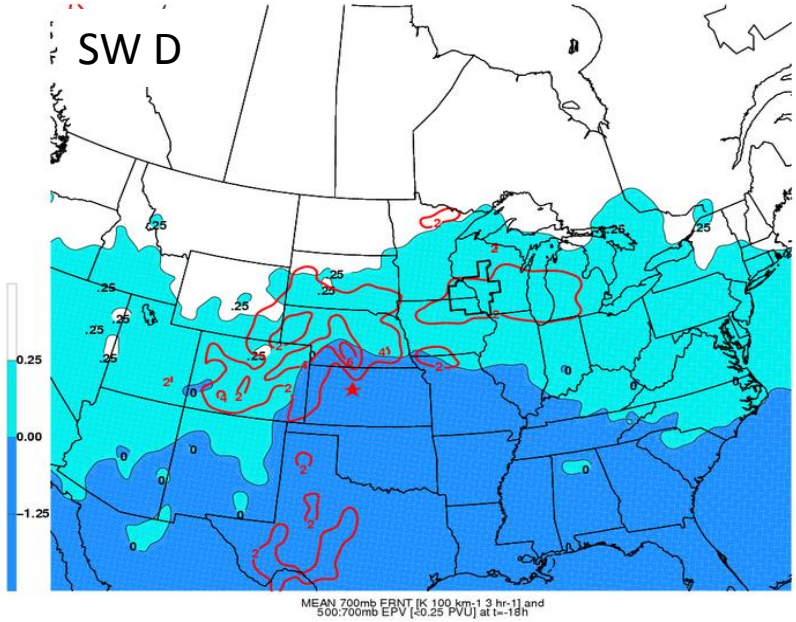
850mb Low indicated by "★"

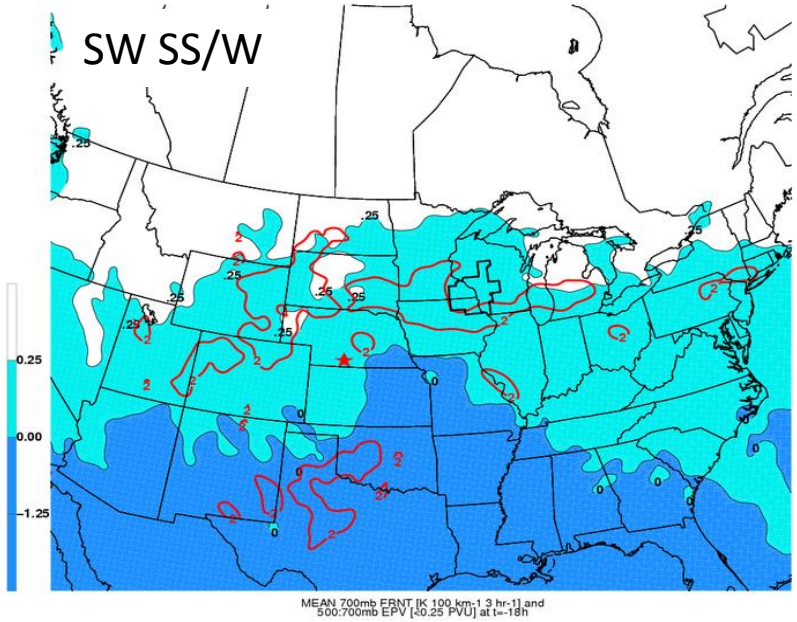


Time: t-6hrs Heavy Snow Begin

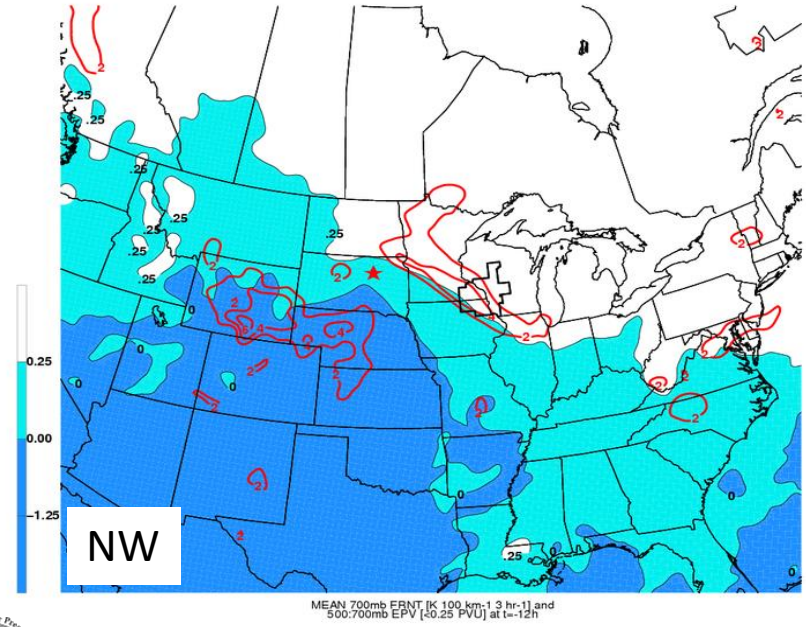
- ALL: Weak static stability above the frontogenesis zone present in all cases.
- ALL: No upright instability present in the heavy snow area.
- ALL: Instability maximizes at Heavy Snow Begin to Heavy Snow time, then decreases (being released).
- NW: Instability is located higher vs. SW.
- SW: Instability is also located closer, vertically, to the frontogenesis zone.

700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**





850mb Low indicated by "★"



Time: Heavy Snow Begin (00h)

- ALL: Weak static stability above the frontogenesis zone present in all cases.
- ALL: No upright instability present in the heavy snow area.
- ALL: Instability maximizes at Heavy Snow Begin to Heavy Snow time, then decreases (being released).
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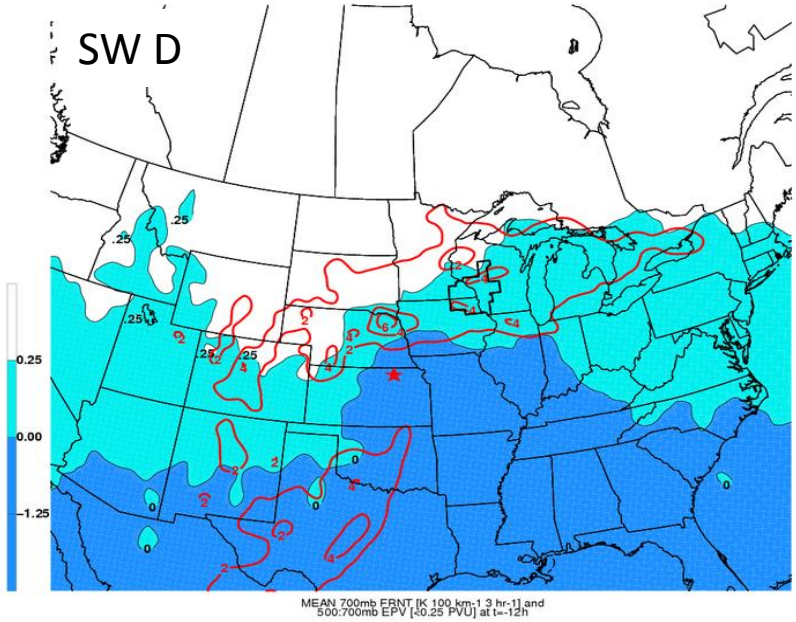
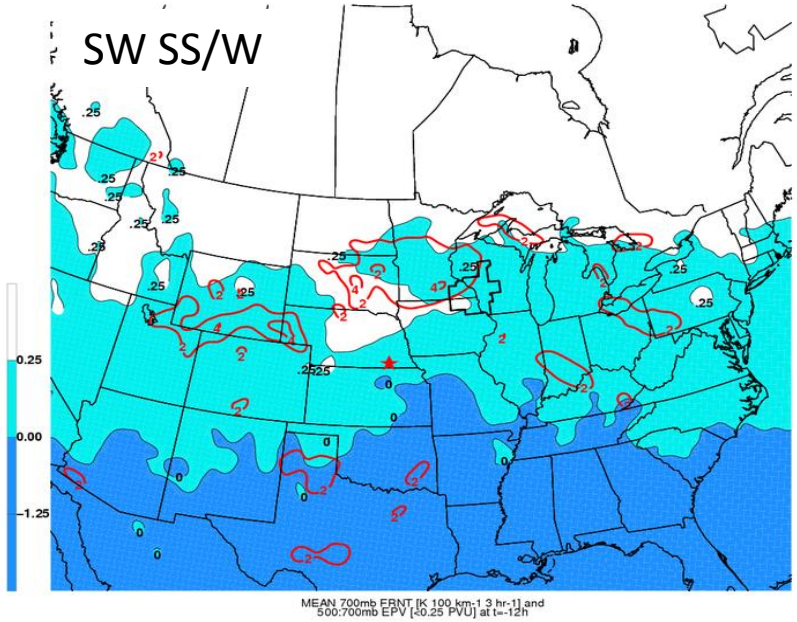
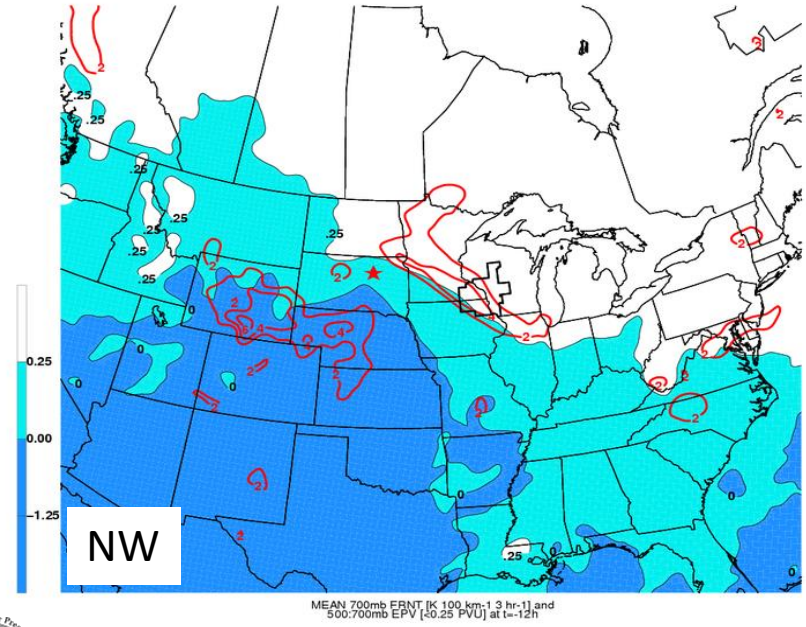
700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**

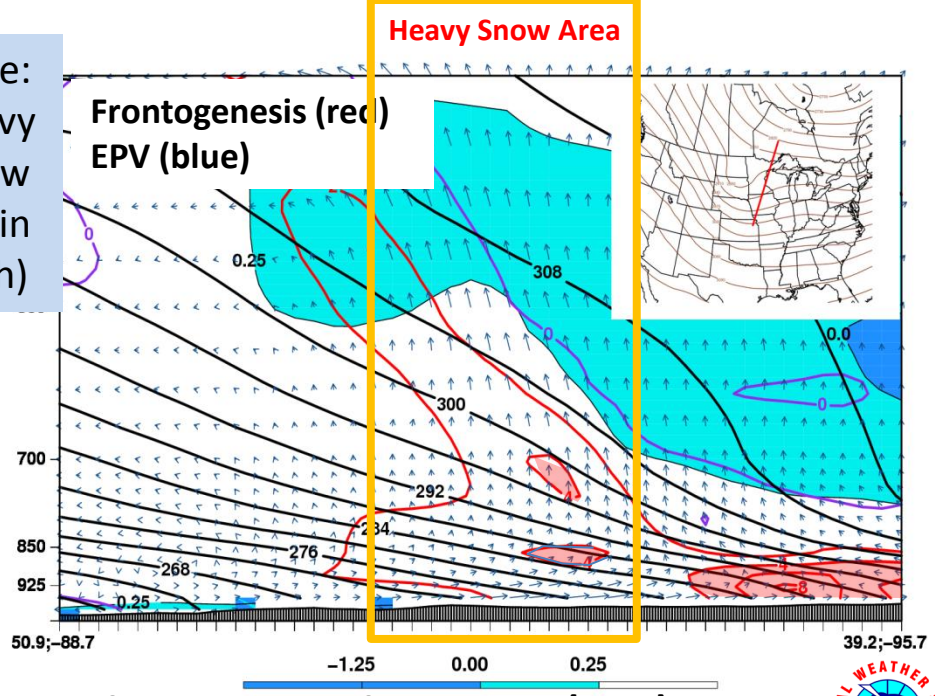




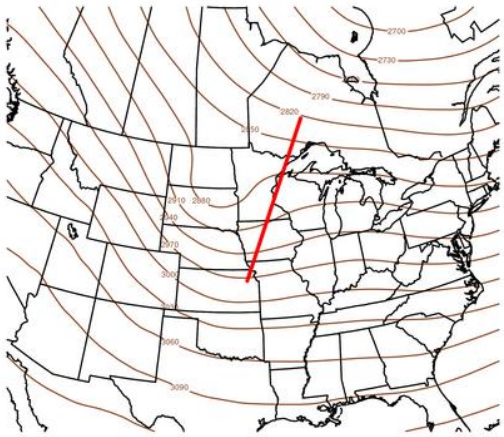
850mb Low indicated by "★"

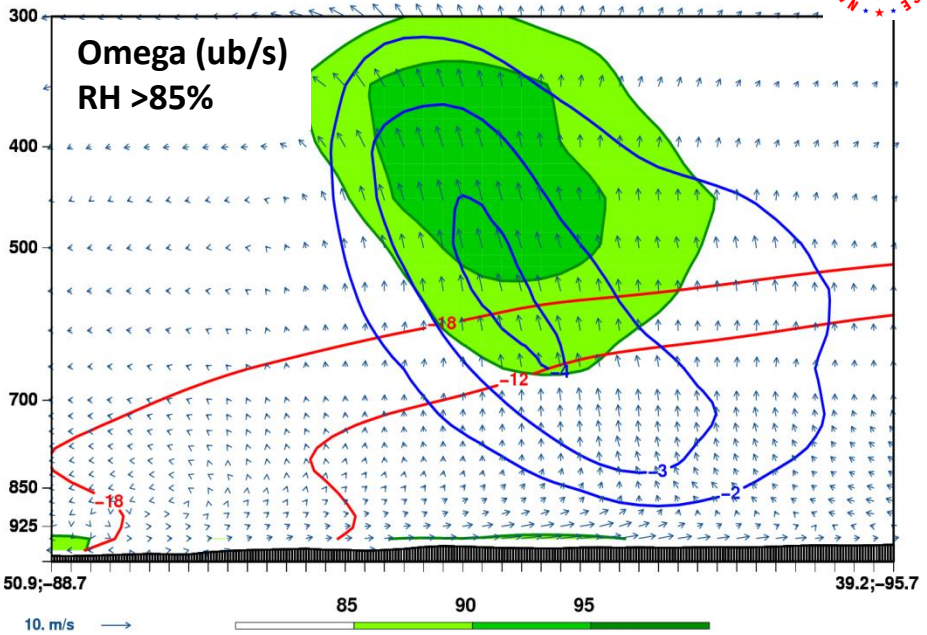


Time: Heavy Snow Begin (00h)

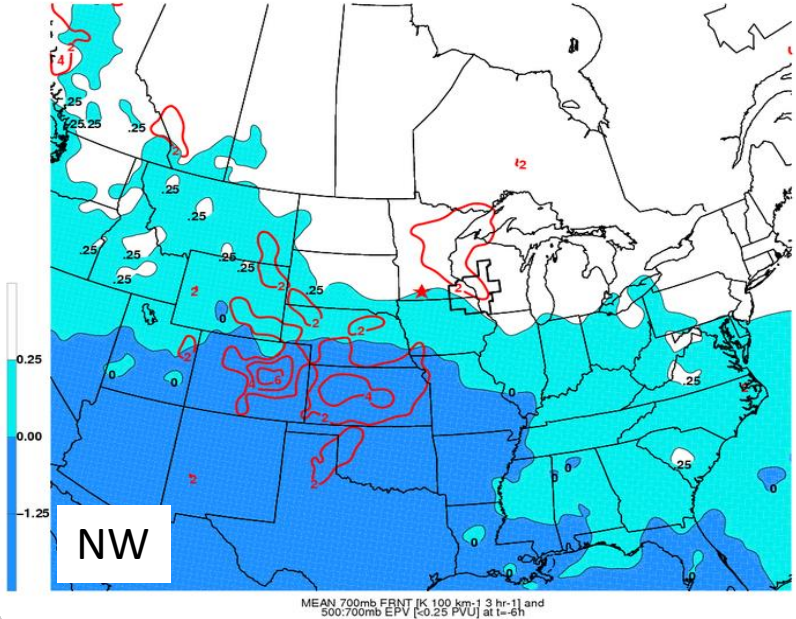


700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**





850mb Low indicated by "★"



Time: Heavy Snow

(06h)

- ALL: Weak static stability above the frontogenesis zone present in all cases.
- ALL: No upright instability present in the heavy snow area.
- ALL: Instability maximizes at Heavy Snow Begin to Heavy Snow time, then decreases (being released).
- NW: Instability is located higher vs. SW.
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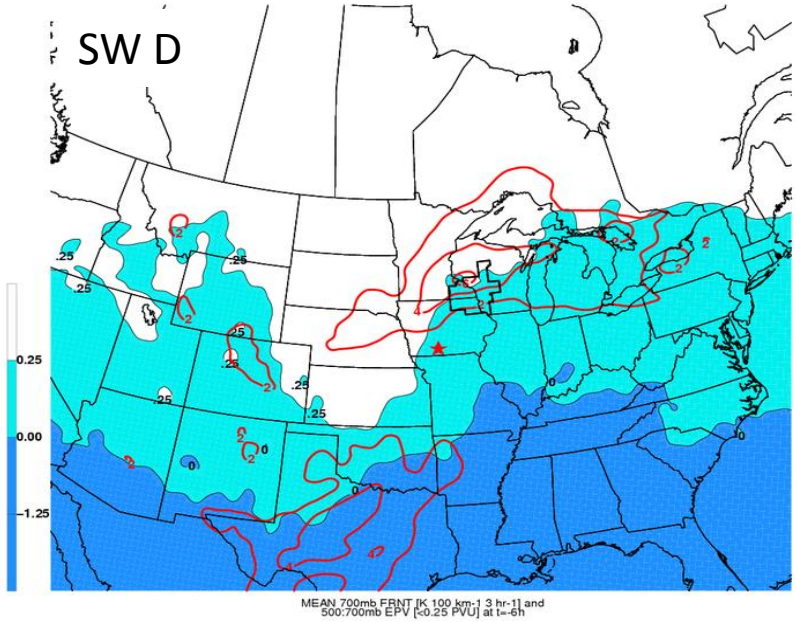
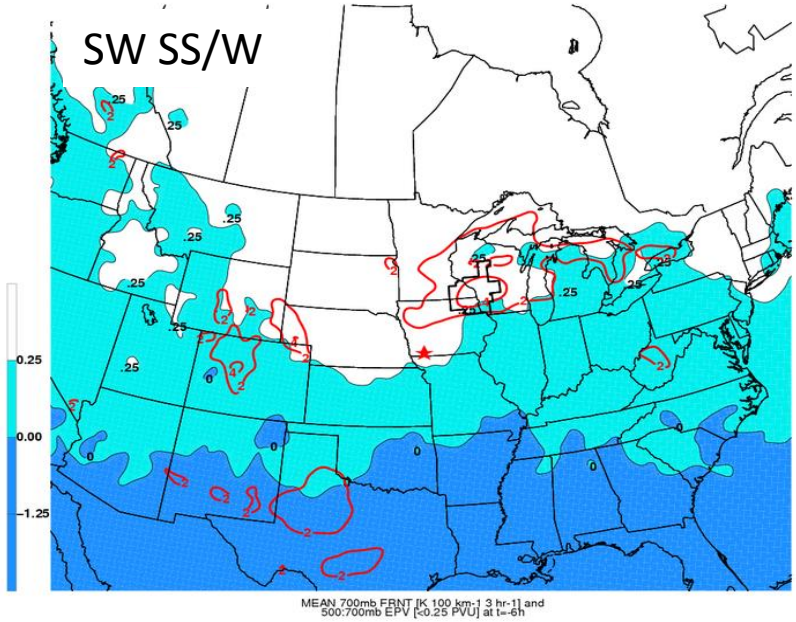
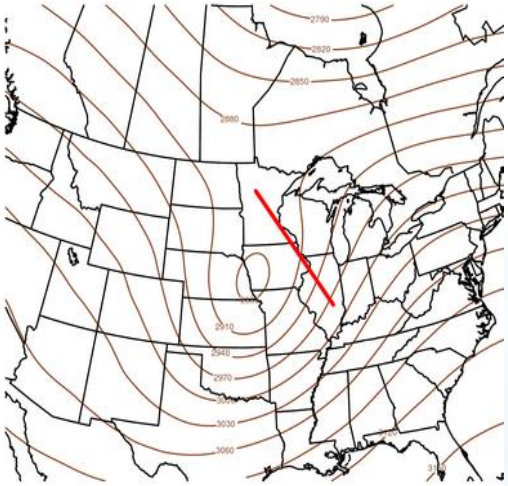
700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**



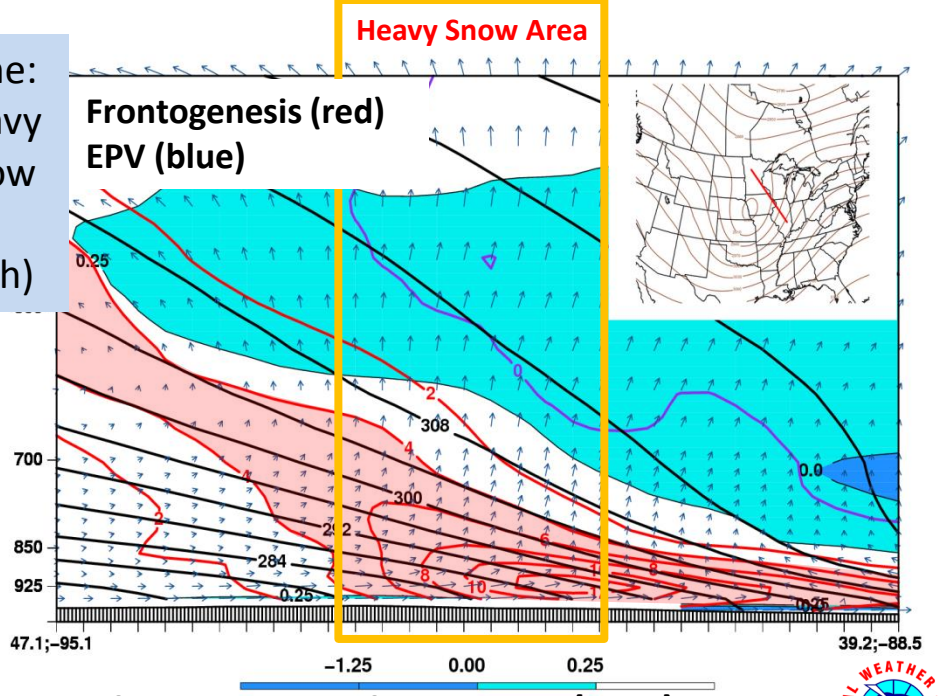


850mb Low indicated by "★"

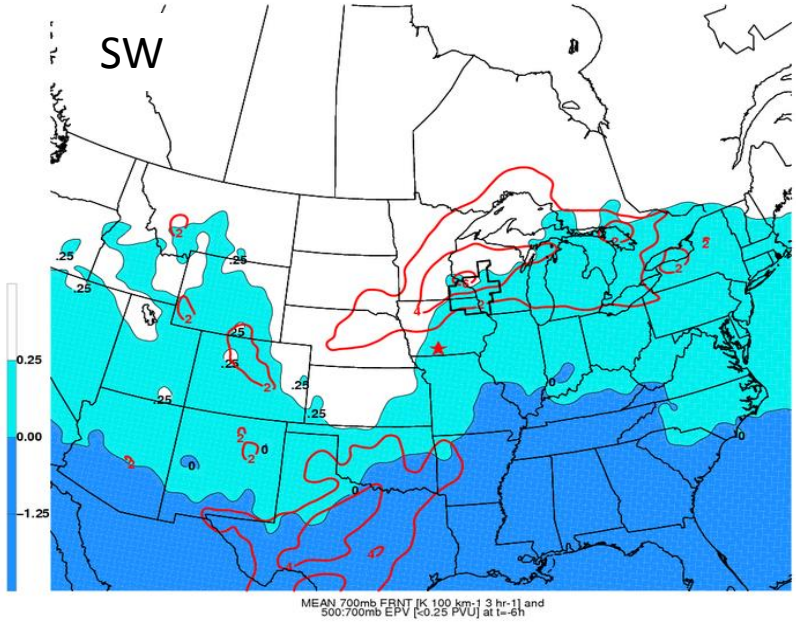


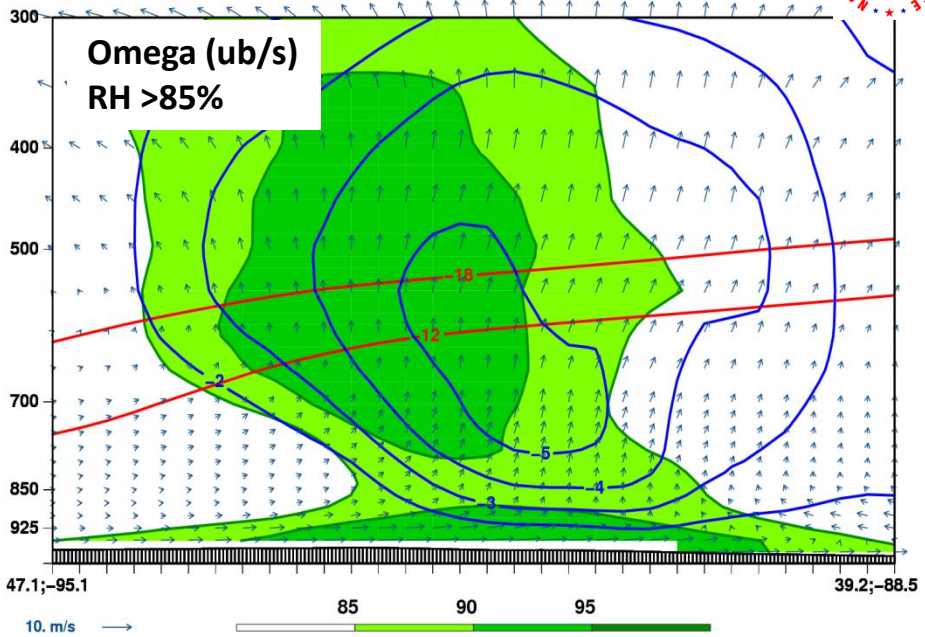
Time:
Heavy
Snow

(06h)

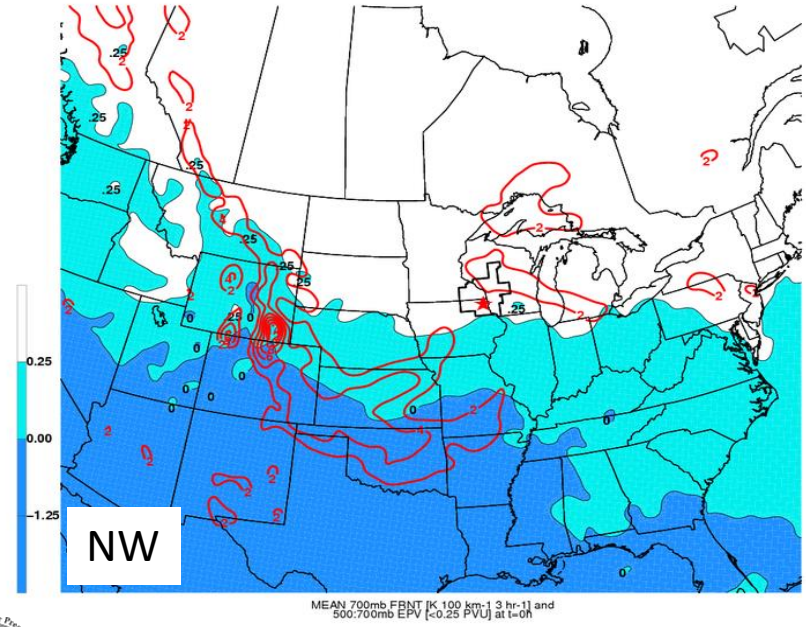


700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**





850mb Low indicated by "★"



Time: Heavy Snow Ending (12h)

- ALL: Weak static stability above the frontogenesis zone present in all cases.
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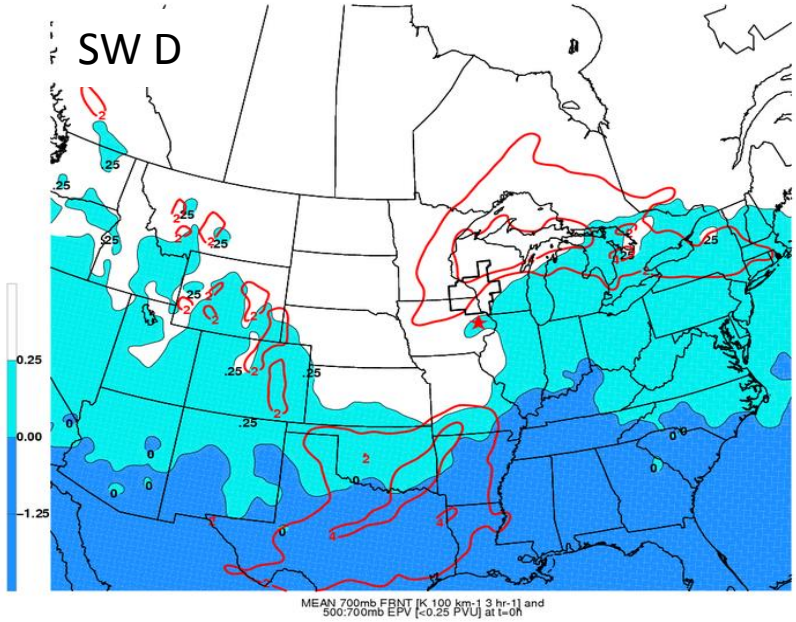
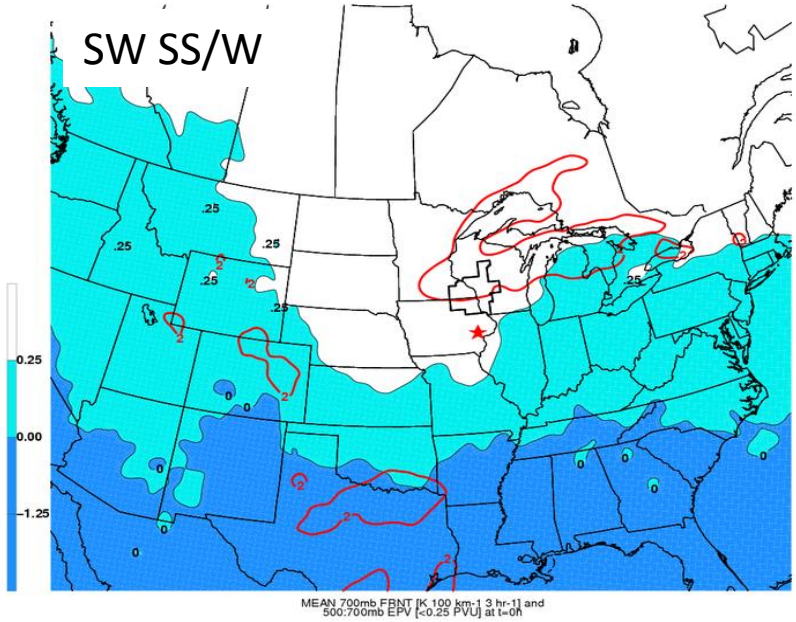
700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**





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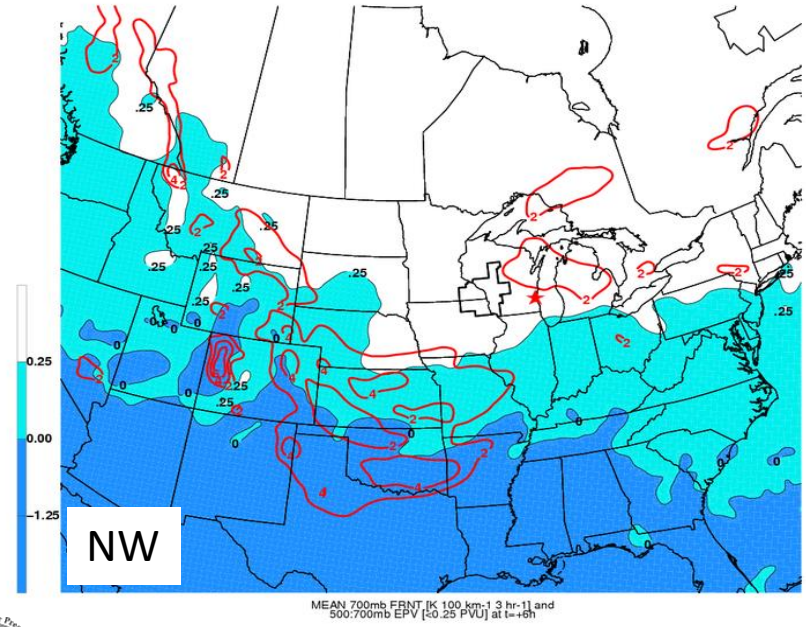

Time: T+6hrs Heavy Snow End

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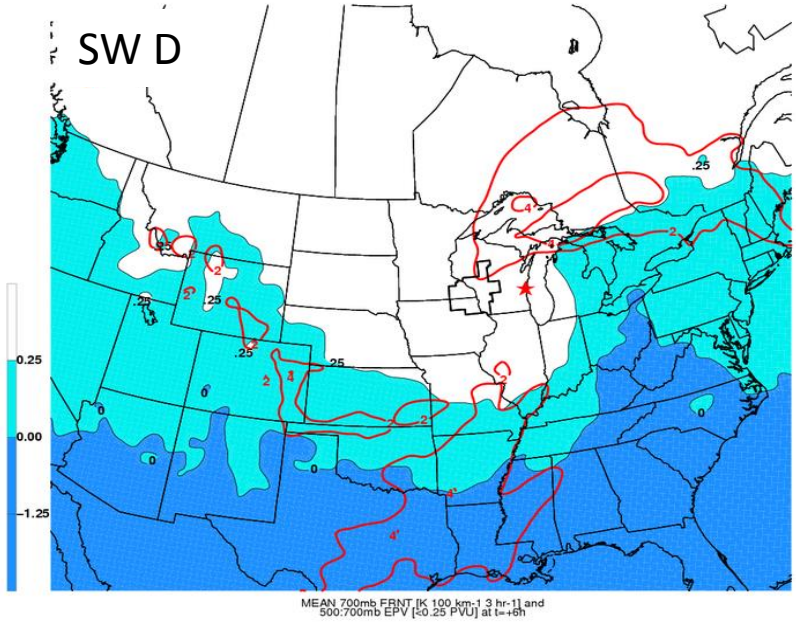
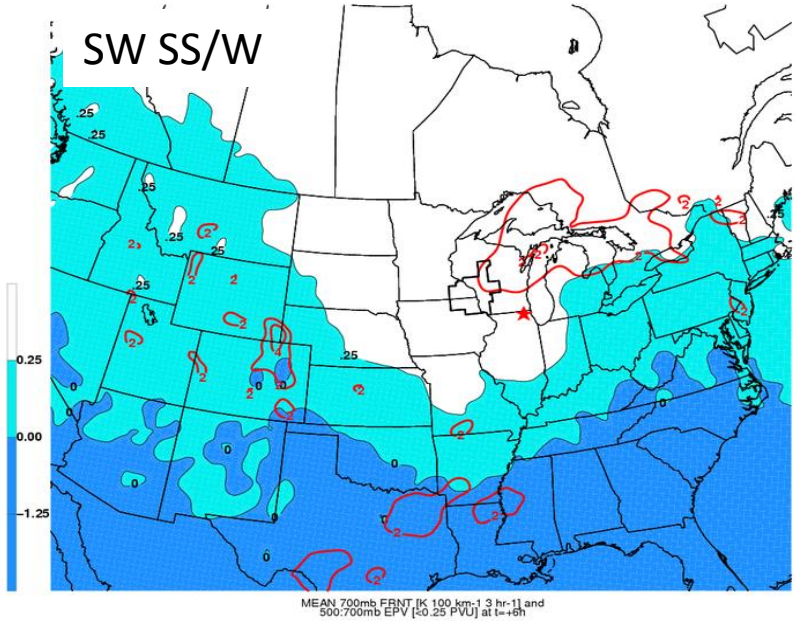
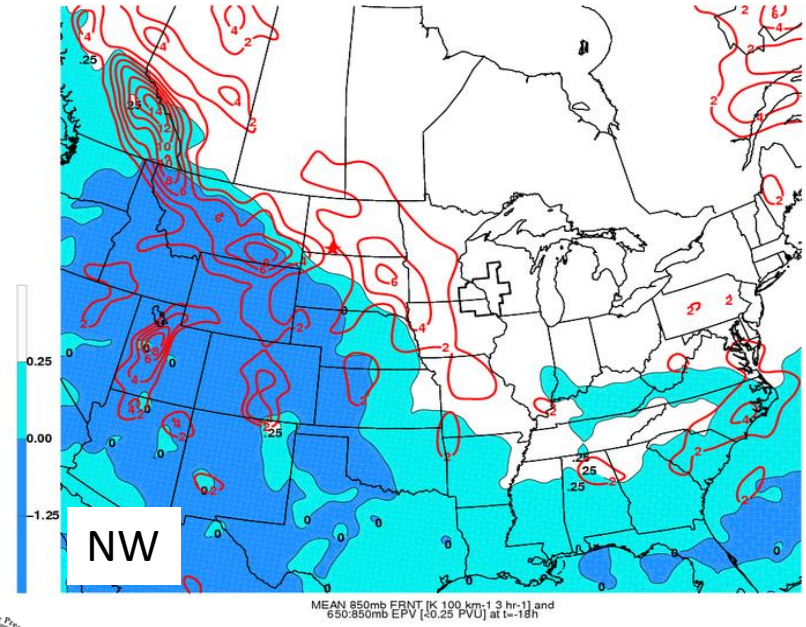
700mb Frontogenesis, **500-700mb Equivalent Potential Vorticity (EPV)**





850mb Low indicated by "★"



Time: t-6hrs Heavy Snow Begin

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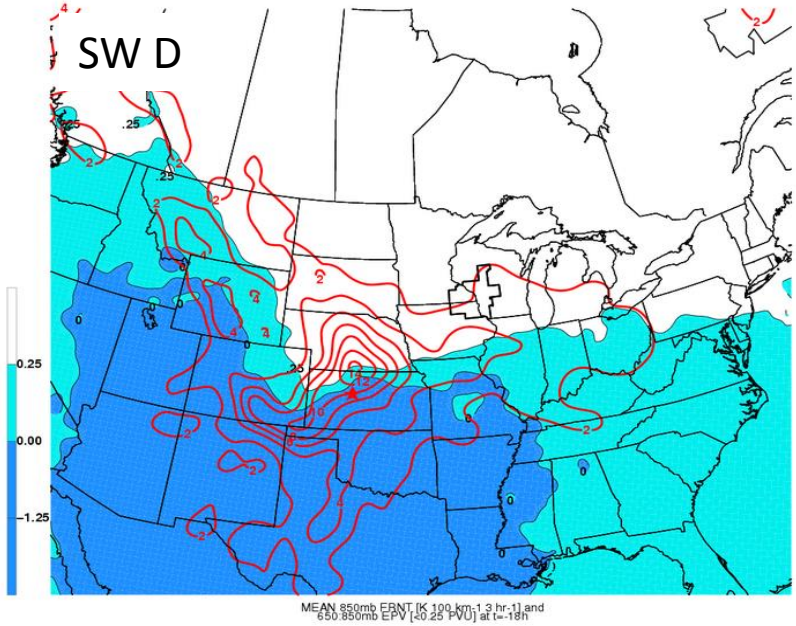
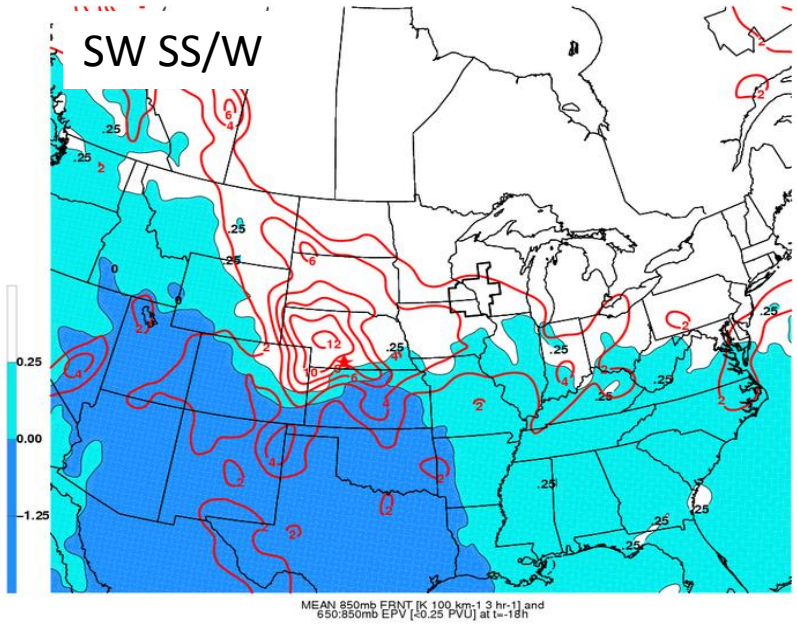
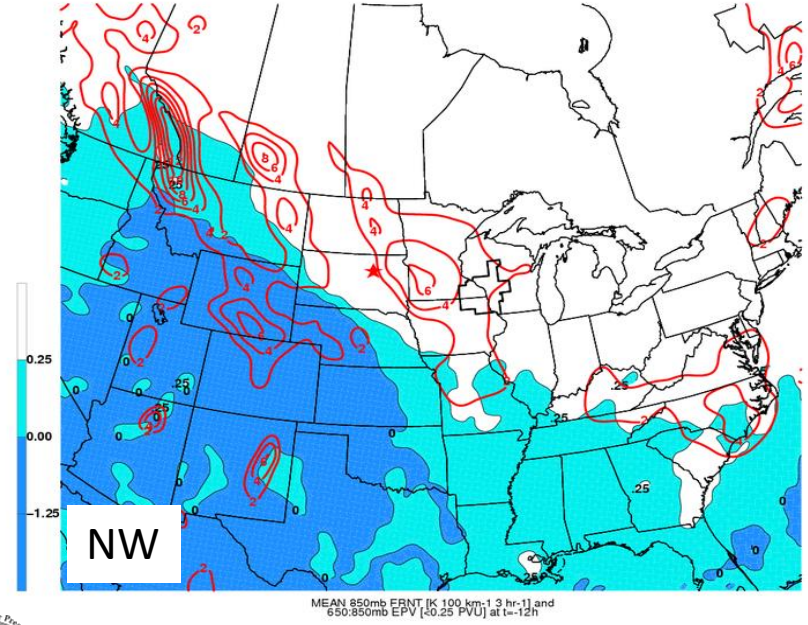
850mb Frontogenesis, **650-850mb Equivalent Potential Vorticity (EPV)**





850mb Low indicated by "★"



Time: Heavy Snow Begin (00h)

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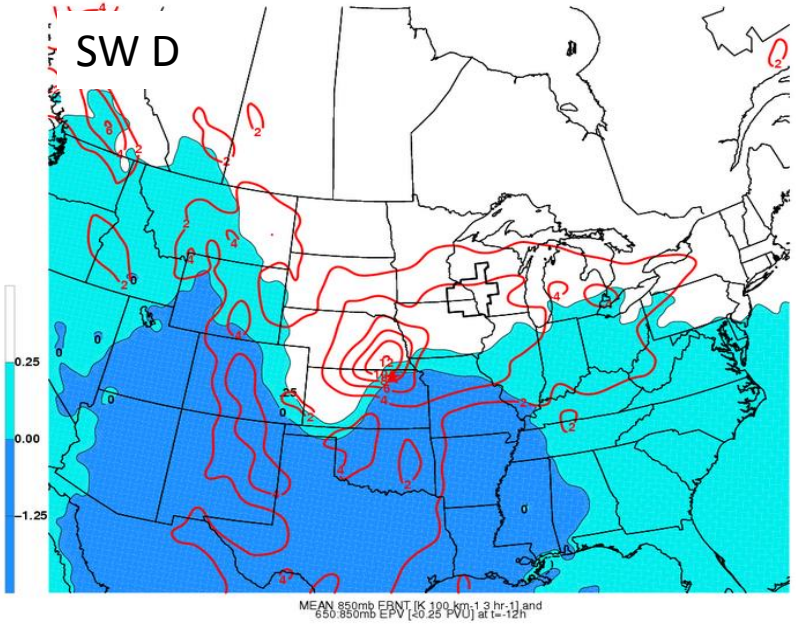

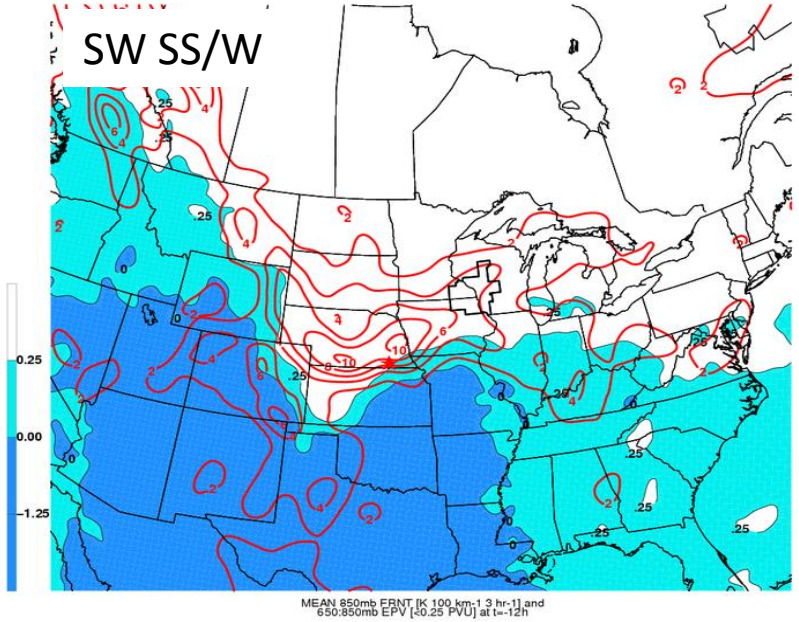

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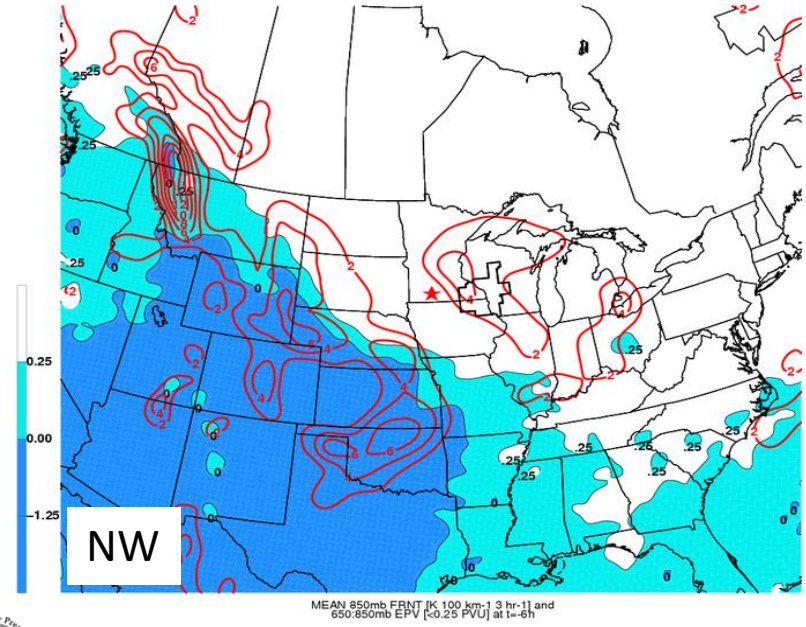

Time: Heavy Snow

(06h)

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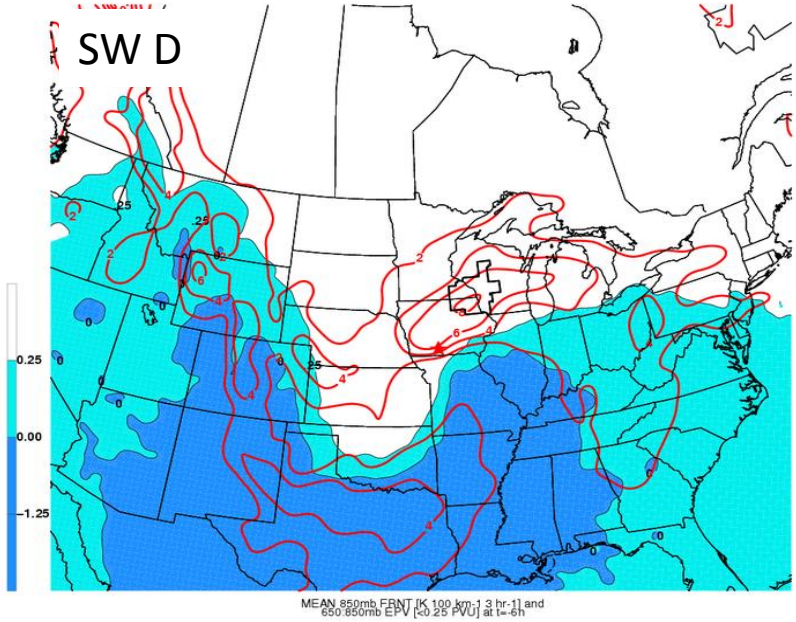

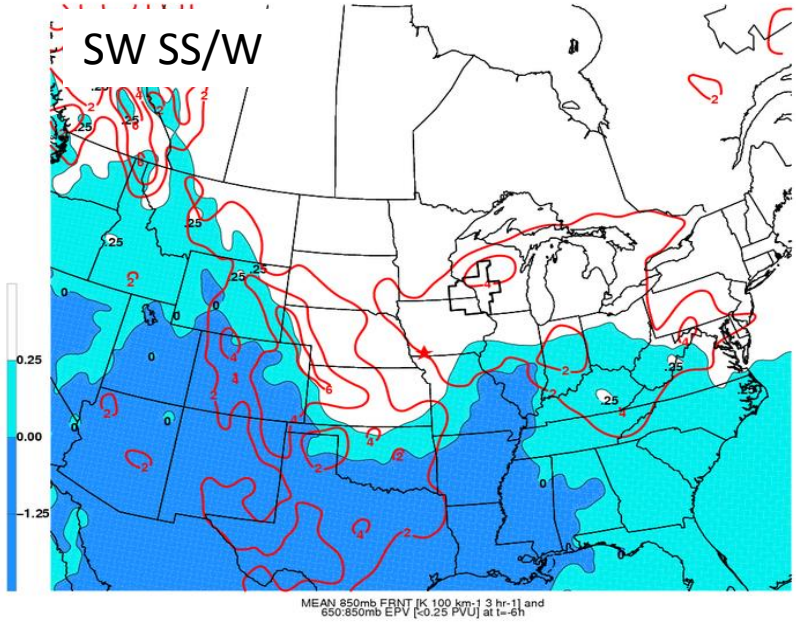

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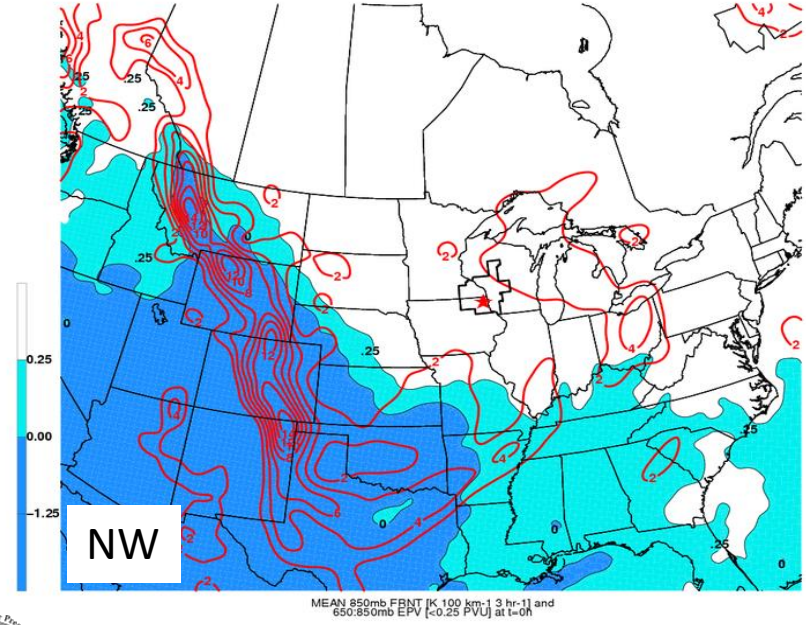

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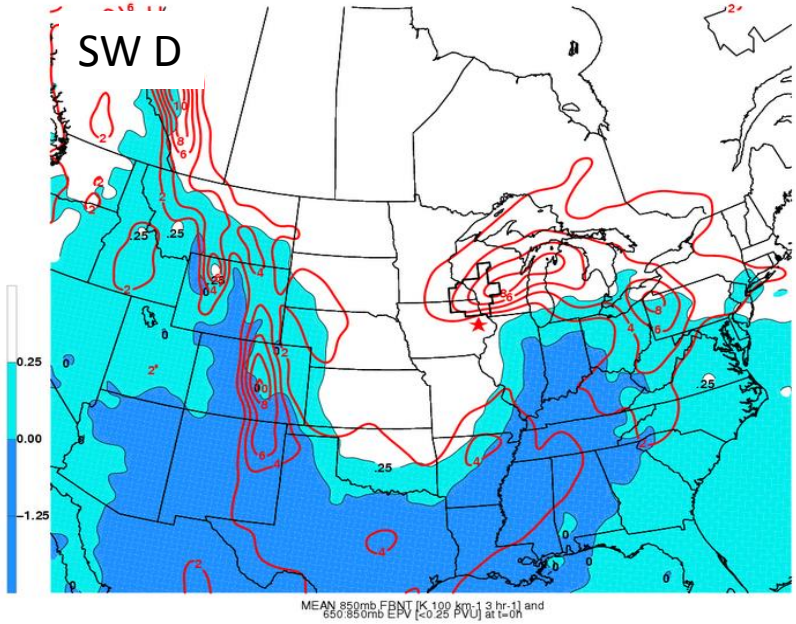

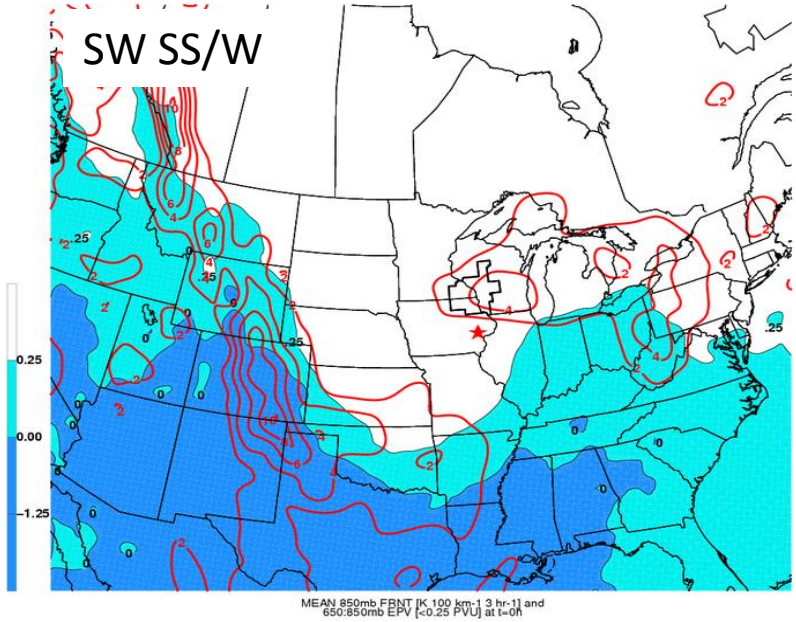

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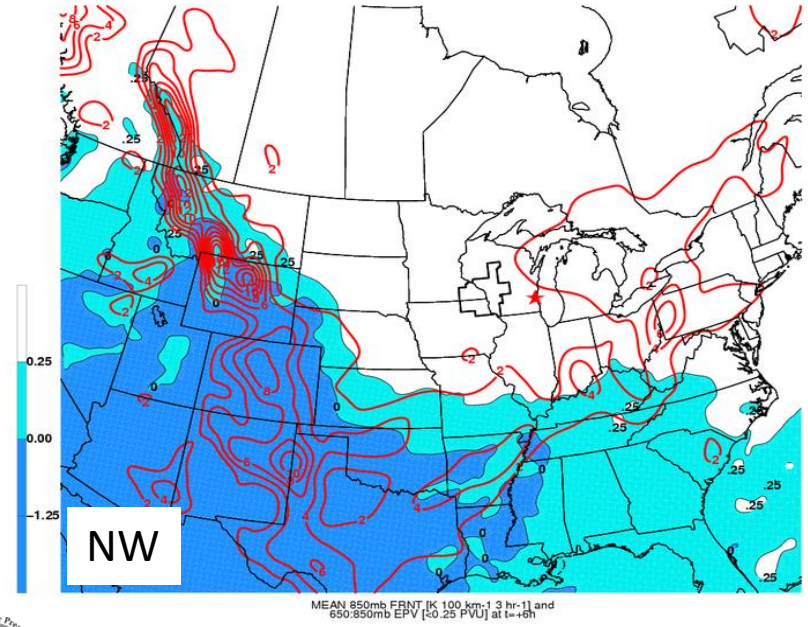

Time: T+6hrs Heavy Snow End

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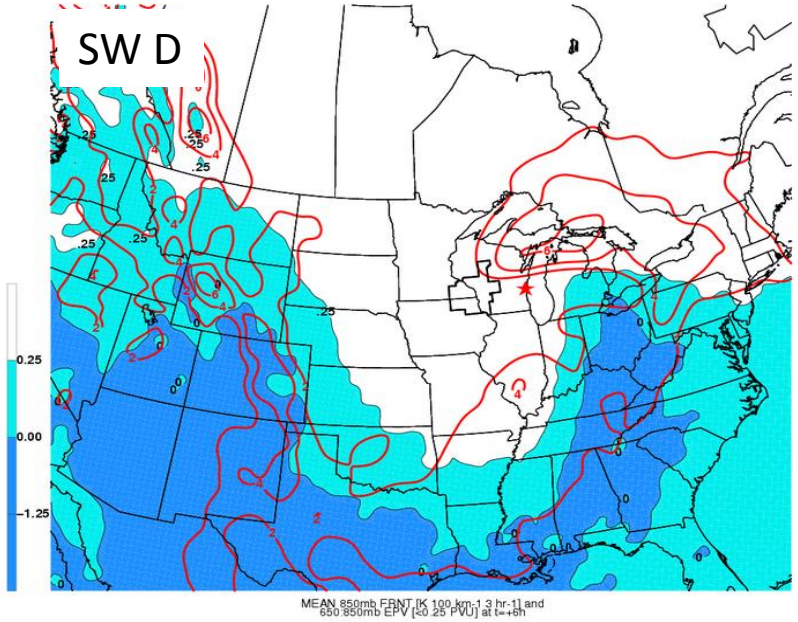

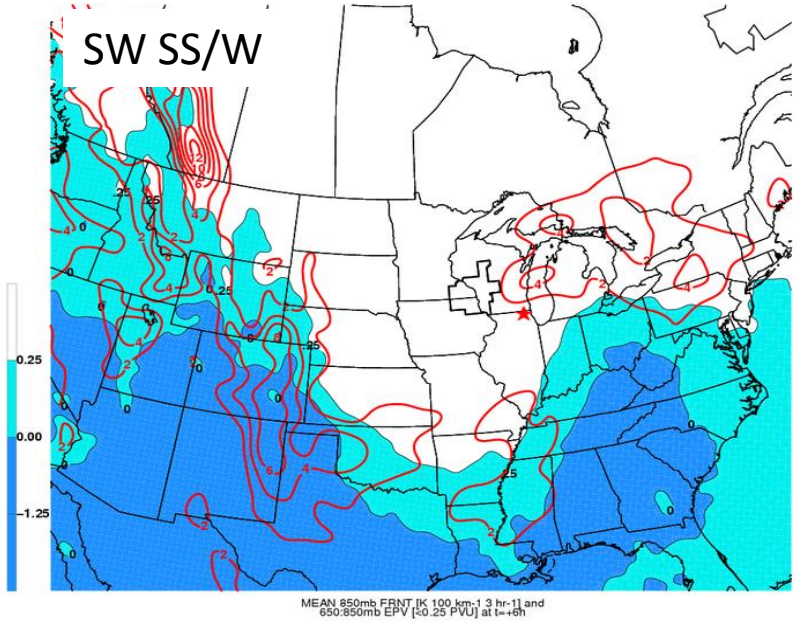

850mb Low indicated by "★"

Summary

- Research provides a nice climatology on the mass and kinematic fields and the forcing for heavy snow.
- SW D cases show stronger forcing resulting in the deepening system
  - 300mb jet exit region adding to downscaled lift
  - PV reservoir merging

Summary

- Frontogenesis in place 1000+ mi downstream of low center.
  - *Duration* of snow favored with low track parallel to frontogenesis axis.
- Weak static stability in place for all cases.
  - More closely situated above 700mb Fgen than lower levels.
- Dendrite crystals may impact NW flow snow ratios.

Environments Favorable for Heavy Snow Across the Upper Mississippi River Valley Region: A Composite Study

Dan A. Baumgardt[1], Dan Jones[1], Scott Watson[2], Dr. Charles Graves[3], Chad Gravelle[3], and Jayson Gosselin[3]

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